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PRELIMINARY NOTES ON CINCINNATIAN AND LEXINGTON FOSSILS.[1]

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The Saluda bed is typically exposed at Madison, Indiana, but the name was taken from Saluda creek, eight miles southwest of Madison, because the latter name was preoccupied. At Madison it consists chiefly of argillaceous limestones forming massive beds, but near the base the rock weathers to thinner layers which northward, in Jefferson and Ripley counties, become more conspicuous and have there, on account of their thin bedding, been called shales. Very fine, microscopic grains of sand are present, which become more abundant southwards, so that in west-central Kentucky the rocks feel gritty between the fingers. The name Saluda was introduced chiefly on lithological grounds, to distinguish the comparatively unfossiliferous fine-grained, argillaceous limestones, forming massive beds at numerous falls, from the underlying thin, blue limestones, interbedded with considerable clay, both richly fossiliferous. As a matter of fact, the Saluda of Indiana and northern Kentucky contains a considerable variety of species, but usually the individual specimens are few, or the specimens do not weather out well and very little effort has been made to collect them excepting at two horizons: at the top, in the Hitz layer, and at the base, immediately above the chief *Columnaria* layer. An effort was made to introduce a paleontological base for the Saluda bed, and the chief *Columnaria* layer, and, in its absence, the massive *Tetradium* layer, was chosen for this purpose. Unfortunately, these coral layers cannot be traced south of Hanover, Indiana, and beyond this locality, only the lithological distinctions can be utilized.

Recently Prof. E. R. Cumings has traced the Saluda northward in Indiana and has shown that it wedges in between the Liberty and Whitewater beds. In Ohio, I have seen the strata thus iden-

[1] Published by permission of Prof. C. J. Norwood, State Geologist of Kentucky. The accompanying plates are the property of the Kentucky Geological Survey.

tified at only one locality three miles north of Oxford, on the east side of Four Mile creek, along a branch coming in from the northeast. The characteristic Whitewater fauna is found a quarter of a mile up the branch. Undoubtedly, other localities will be found in the western part of this state, but no corresponding strata are known at present anywhere along the eastern line of outcrop, from Dayton, Ohio, to Concord, Kentucky, and southward.

There are two *Hebertella insculpta* horizons in Ohio. Only the upper one of these horizons was known at the time the name Waynesville bed was introduced, and this upper *Hebertella insculpta* horizon was chosen as the base of the Liberty bed. In reality, there is a greater stratigraphic break immediately above the upper *Hebertella insculpta* horizon, so that the latter should form the top of the Waynesville bed. This upper *Hebertella insculpta* horizon may be traced through Indiana as far southward as Madison. However, within the limits of Jefferson county, the number of specimens at this horizon rapidly becomes less and at Madison only careful search will result in locating the horizon. Recently, Mr. John F. Hammel and the writer located this horizon accurately along the Hanging rock road at Madison, 32 feet below the base of the chief *Columnaria* layer, agreeing essentially with my measurements 5 years ago. *Dinorthis subquadrata* makes its first appearance about 4 feet farther up.

The same species of corals which are found in southern Indiana at the base of the Saluda bed, 32 feet above the top of the Waynesville bed, occur in Kentucky, on the western side of the Cincinnati geanticline, from Jefferson county as far south as the central part of Casey county, but below the lowest horizon containing *Dinorthis subquadrata* and various Liberty fossils. Since this fossiliferous horizon underlies the southern continuation of the Saluda bed it seems evident that the Kentuckian coral horizon here mentioned, which is found at a still lower level, belongs not at the base of the Saluda but at the base of the southern extension of the Liberty bed.

At these coral horizons in Indiana and Ohio the number of specimens of corals often is so great that the name coral reef seems pertinent. For the coral horizon at the base of the Saluda bed the name *Madison coral reef* was introduced and for that at the base of the Liberty bed, the name *Bardstown coral reef*.

Another coral reef of much less importance occurs in the lower

part of the Waynesville bed. In consists chiefly of *Columnaria* with occasional localities in which *Tetradium* is common, and extends from the western edge of Henry county, in Kentucky, as far as the northwestern edge of Nelson county. This may be called the *Fisherville coral reef*, since one of the typical exposures occurs along the railroad west of Fisherville, and another on the road from Fisherville to Jeffersontown.

The most diligent and effective student of the vertical distribution of Richmond fossils undoubtedly has been Dr. George M. Austin of Wilmington, Ohio. To him the writer has been indebted in ways too numerous to mention. Recently it has become evident that the Waynesville bed includes several very distinct divisions to which it would be convenient to assign names. These divisions have been worked out in collaboration with Dr. Austin, and are founded largely on his labors. Three divisions have been adopted in the present paper, in descending order:

Blanchester division.
Clarksville division.
Fort Ancient division.

The Blanchester division includes all between the upper and lower *Hebertella insculpta* horizons and is typically exposed along Stony Hollow, northwest of Clarksville, but is well exposed also a mile west of Blanchester, from which the name was selected. At the lower *Hebertella insculpta* horizon, *Catazyga headi*, and *Dinorthis carleyi-insolens*, occur at various localities. *Strophomena nutans*, *Strophomena neglecta*, and a precursor of *Strophomena vetusta* occur over wide areas and usually in considerable abundance in the middle layers of this division. *Rhynchotrema dentata* occurs in the upper one of two layers in which an abundance of *Rafinesquina* is present, chiefly turned up on edge. *Austinella scovillei* occurs in the corresponding division at Oregonia, Ohio, 5 feet below the upper *Hebertella insculpta* horizon. It is the richest part of the Waynesville bed in the variety of its fauna. East of the Cincinnati geanticline the Blanchester fauna may be traced as far south as Owingsville, Kentucky, although the lower *Hebertella insculpta* layer cannot be traced beyond Adams county, Ohio. On the western side of the geanticline the fauna has been traced as far south as Canaan, Indiana, although *Dinorthis carleyi-insolens* has not been found south of Franklin county.

The Clarksville division is typically exposed along Stony Hollow northwest of Clarksville, Ohio; but excellent exposures occur also over a mile southeast of Fort Ancient and in the Blacksmith Hollow at Oregonia. It extends from the *Orthoceras fosteri* horizon to the lower *Hebertella insculpta* layer. The *Orthoceras fosteri* horizon is exposed along Stony Hollow immediately north of the bridge crossing the little stream forming the hollow. It consists of a layer of clay 5 feet thick, containing *Tetradium*, *Labechia*, various small incrusting bryozoans including *Spatiopora montifera*, as well as a considerable number of *Orthoceras fosteri*. The Clarksville division is notable for introducing a part of the fauna usually considered typical of the Richmond, but not found in the Fort Ancient division of the Waynesville. Within 5 feet of the top of the *Orthoceras fosteri* bed the following species are introduced: *Streptelasma vagans*, *Plectambonites sericea*, *Strophomena planumbona*, *Strophomena sulcata*, and a variety of *Rhynchotrema* resembling *Rhynchotrema perlamellosa*. Within 7 feet of the *Orthoceras fosteri* layer *Leptæna richmondensis* comes in. As a matter of fact, *Streptelasma vagans* is known at the base of the Waynesville bed, at Concord, Kentucky, but this is its only known occurrence at this horizon, and it does not yet characterize the Waynesville bed over any extended territory. The Clarksville fauna may be traced southward as far as Wyoming, in Kentucky, and southern Jefferson county, in Indiana. Farther south, the lithological characteristics of the Waynesville bed change rapidly and the accompanying paleontological features change at the same time, necessarily.

The Fort Ancient division is typically developed along the stream crossed by a north and south road a little over a mile southeast of the Fort. It is characterized by the abundant presence of *Dalmanella jugosa*, with the exclusion of all other brachiopoda and corals considered characteristic of the Richmond. Since *Dalmanella jugosa* has a considerable vertical range in the Arnheim bed in eastern Indiana, and occurs just below the *Dinorthis carleyi* horizon near the middle of the Arnheim bed at numerous localities in Ohio, this absence of characteristic Waynesville brachiopoda becomes more striking. The Fort Ancient division of the Waynesville, moreover, is noteworthy on account of the presence of numerous specimens of certain species of lamellibranchs, including *Anomalodonta gigantea*, *Modiolopsis concen-*

trica, *Modiolopsis pholadiformis*, *Opisthoptera fissicosta*, and *Pterinea demissa*. In addition to these, *Rafinesquina loxorhytis* is abundant. Now, as a matter of fact, a very similar assemblage of fossils occurs in the upper part of the Arnheim bed in the eastern part of Indiana and suggests the idea that the Fort Ancient division of the Waynesville bed belongs with the upper part of the Arnheim, rather than with the Clarksville and Blanchester divisions of the Waynesville bed. The first specimens of *Bythopora meeki* were noticed 28 feet above the base of the Fort Ancient division, but it may occur lower. The Richmond form of *Platystrophia laticosta* comes in 7 feet below the base of the *Orthoceras fosteri* zone.

The lower part of the Garrard sandstone of central Kentucky consists of massive argillaceous and more or less siliceous fine-grained limestones, with few fossils, differing conspicuously from the thinner bedded argillaceous limestones, interbedded with considerable clay, which overlie it and form most of the upper part of this Garrard sandstone. To the lower, massive part the name Paint Lick bed was applied. The overlying part was correlated with the Mount Hope bed on account of the presence of *Strophomena maysvillensis*, and other fossils which northward begin their range with the Mount Hope bed. The lower or massive part, called the Paint Lick bed, was correlated with the upper Eden, because it was believed that it could be traced stratigraphically northward into beds containing *Dekayella ulrichi* and other characteristic Eden fossils.

The underlying Eden beds in central Kentucky, were included in the Million bed. This bed includes the southern continuation of the Southgate bed and, at its base, a peculiar fauna including: *Climacograptus typicalis*, *Ectenocrinus simplex*, *Lichenocrinus crateriformis*, *Heterotrypa foerstei*, *Crepipora venusta*, *Escharopra falciformis*, *Arthropora cleavelandi*, *Monotrypa subglobosa*, *Constellaria florida-prominens*, *Dalmanella emacerata*, *Dalmanella multisecta*, a species of *Hebertella*, a species of *Platystrophia*, *Plectorthis* (*Eridorthis*) *nicklesi*, *Plectorthis* (*Eridorthis*) *rogersensis*, *Clitambonites diversus-rogersensis*, *Plectambonites sericea*, *Strophomena hallie*, a *Cyclonema* with a rather low spire, *Fusispira sulcata*, *Cyrtolites ornatus*, *Byssonychia vera*, *Primitia centralis*, *Ceratopsis chambersi*, *Trinucleus concentricus*, a species of *Ceraurus*, one of *Acidaspis* belonging to the *Acidaspis anchoralis* group, and a species

of *Calymmene* which differs from that usually identified as *Calymmene callicephala* by its smaller size and by the presence of numerous granules, larger and more conspicuous than in the latter species. The anterior border of the cephalon appears less strongly elevated anterior to the glabella. For this form, the name *Calymmene callicephala-granulosa* is suggested here. The typical specimens are found in the lower part of the Eden formation, at Cincinnati, Ohio. My chief object in referring to this horizon at Rogers Gap at the present time is to call attention to the fact that this fauna is now known to have a wide distribution in central Kentucky and evidences of its existence are being found farther northward. The exposures as far north as Sadieville are practically continuous. The same fauna occurs also north of Ford, near Hutchison, at the Lower Blue Lick Springs in the northern edge of Nicholas county, and northward. Recently, *Plectorthis* (*Eridorthis*) *nicklesi*, and *Plectorthis* (*Eridorthis*) *rogersensis* have been found, in strata formerly included in the Lower Eden, at various localities between Cincinnati and Foster. Among these localities are the quarries at Ivor, the lower part of Nine-mile creek, and the exposures below Fort Thomas.

Recent observations by E. O. Ulrich indicate that along the Ohio river the lower part of the strata formerly included in the Lower Eden include a much larger Fulton element than formerly suspected, and that the typical Economy fauna begins higher up. This lends additional interest to the Rogers Gap fauna, whose peculiarities were recognized in part even from the earliest observations. The exact relationship between the Rogers Gap fauna and that of the extended Fulton section, has not been worked out; however, it is known that both species of *Eridorthis* occur in this extended Fulton.

Sections occupying a similar position at the base of the Eden formation, and which apparently should be distinguished from the Economy bed, occur at Sparta, and west of Drennan Springs, Kentucky.

The term Nicholas bed was intended to include only the upper part of the Cynthiana formation, consisting of rather coarse-grained limestone with relatively few fossils. This part is typically exposed between Pleasant Valley and Millersburg. Exposures occur at least as far south as Winchester, and apparently also in the western part of Madison county. Toward the north and northwest the limestones become more argillaceous, fine grained layers are more frequent, and fossils are more abundant.

The underlying part, characterized by the presence of a considerable fauna, including *Orthorhynchula linneyi*, *Hebertella maria-parksensis*, *Eridotrypa briareus*, *Constellaria emaciata*, *Homotrypella norwoodi*, is called the Greendale bed, this designation having been given at an earlier date to the southern extension of this bed in Fayette county, Kentucky.

The northern extension of this fauna along the Ohio river, east of Cincinnati, especially the localities at Point Pleasant, Ivor, Carnestown and Foster, have been known a considerable time, and a very characteristic fauna has been collected at Ivor, Ky. At the latter locality, *Orthorhynchula linneyi* occurs, occasionally, at the level of the railroad. At Carnestown, a single specimen of *Orthorhynchula linneyi* was found 10 feet above the level of the railroad, at the top of a contorted layer of fine-grained limestone. This probably is at about the same horizon as the contorted layer of limestone which formerly was exposed just above railroad level at the quarry a quarter of a mile east of Ivor.

The interval from this *Orthorhynchula linneyi* horizon, at Ivor and Carnestown, Kentucky, down to the *Callopora multitabulata* horizon is approximately 50 feet. It is this interval which forms the lowest fifty feet in the Ordovician section at Point Pleasant. It is this interval which includes the Point Pleasant beds of Professor Orton. At the time Professor Orton was writing his report, on the Geology of the Cincinnati Group, in volume I of the Ohio Geological Survey, rock was quarried at river level in the western edge of Point Pleasant and sent by river barges to Cincinnati. These were the lowest rocks exposed in the state and must have formed the base of his 50 foot section. The quarrying operations were continued until most of the rock which could be easily removed had been quarried out and the overload was too great to make further work at these lower levels profitable. Even before the lower quarries at river level were abandoned those above the level of the pike were opened up, but on that account it must not be assumed that Professor Orton's measurement of 50 feet began with the road level in place of the river level.

Moreover, the base of the shaly section at Point Pleasant, Ohio, is located about 113 feet above the Ohio river. This shaly section undoubtedly formed the base of the Eden shales in Professor Orton's section. If from the underlying part the upper 50 feet were subtracted, as probably equivalent to the River quarry beds

at Cincinnati, the underlying part would have been about 50 feet thick.

Time has dealt unkindly with Professor Orton's type section of the Point Pleasant beds. Formerly the stream passing between the quarries above the road level, a half mile west of Point Pleasant, exposed a very fair section down to the river level. Then a larger culvert was put in and the exposures gradually became covered. At the time this section was investigated by Professor Joseph F. James, (On the Age of the Point Pleasant beds)[1] there was a very fair exposure of the strata from 11 feet above the river level to 22 feet above the river level. Between 22 and 34 feet, there was enough exposed to give some idea of the material forming the section. The beds nearer river level, some of which formerly had been quarried, but only at very low water, had been covered up and the débris at the culvert, the wash of the stream having been checked, covered up the upper part of the section. Professor James unquestionably was correct in assigning the lower 50 feet of the Point Pleasant section, from the level of the culvert down to river level, to the Point Pleasant beds. The rocks exposed above the road level must have been interpreted as River Quarry beds by Professor Orton.

It remains now only to determine what the Point Pleasant beds of Orton are in terms of sections described elsewhere. The only statement that can be made at present is that *Callopora multitabulata*, a species of *Prasopora*, probably *Prasopora simulatrix*, *Zygospira recurvirostra*, *Dalmanella bassleri*, *Strophomena vicina*, a species of *Platystrophia*, and *Plectambonites sericea* occur immediately beneath the Point Pleasant section, at Carnestown, Ky. It is possible that *Callopora multitabulata* formerly may have occurred even at very low water level at Point Pleasant itself, since it occurs a little above river level at the landing at Ivor. At present I know of this combination of fossils only in the Paris bed. *Strophomena vicina* has not been found in the Greendale or Wilmore beds, although occurring in the Paris bed and also at the Flanagan horizon. *Callopora multitabulata* is known both from the Paris bed and from the Wilmore bed but not from the Greendale bed. This is true also of *Prasopora simulatrix*. *Platystrophia* is known both from the Greendale and the Paris beds, and there is no reason

[1] Journal of the Cincinnati Society of Natural History, volume XIV, 1891, p. 93.

why it should not occur in the Wilmore bed, but I have never seen it from that horizon.

For the convenience of those who desire a ready abstract of the classification here in use, the following table is added.

Series.	*Formations.*	*Beds.*
Cincinnatian	Richmond	Elkhorn
		Whitewater
		Saluda
		Liberty
		Waynesville
		Blanchester division
		Clarksville division
		Fort Ancient division
		Arnheim
	Maysville	Mount Auburn
		Corryville
		Bellevue
		Fairmount
		Mount Hope
	Eden	McMicken or Paint Lick
		Southgate
		Economy
	Utica	Fulton
	Cynthiana	Nicholas
		Greendale
		Perryville
Upper Mohawkian	Lexington	Paris
		Wilmore
		Logana
		Curdsville

In this classification the Rogers gap beds appear to belong between the typical Economy and the typical Fulton beds, but require further study before their exact limits are defined. A similar statement might be made also of the Point Pleasant beds, which belong below the *Orthorhynchula* horizon along the Ohio river which is definitely recognized as Greendale, and which probably belong above the Paris bed, but which require further study.

Beatricea undulata, Billings.

(*Plate VIII, Fig. 3.*)

Erect columnar growths with longitudinal rounded ridges separated by broad shallow grooves. The ridges and grooves are not necessarily continuous along the entire length of the stem but neighboring ridges may gradually disappear or run together and be replaced by others farther up the same stem. There frequently is a slight spiral twist to these grooves, which occasionally becomes more pronounced. The specimens found in Kentucky and Indiana usually do not exceed 60 millimeters in diameter but larger specimens are found in Canada.

Geological position. In the lower part of the southern extension of the Liberty bed, in Bullitt, Nelson, and Marion counties, Kentucky. The specimens figured were obtained at Bardstown, Kentucky. The most southern specimens were found 2 miles northeast of Liberty, in Casey county, associated with *Columnaria vacua, Tetradium minus,* and *Labechia ohioensis,* at the base of the Liberty bed. It occurs at the corresponding horizon north of Ophelia, 4 miles north of Richmond, in Madison county.

In Indiana, good specimens have been found a short distance above the chief *Columnaria* layer, near the base of the Saluda bed, along the Hanging rock road, at Madison.

In some specimens of *Beatricea* the longitudinal ridges are much less distinctly defined than in the specimen here figured. Sometimes these ridges are rather indefinite in direction and irregular in elevation, becoming nearly obsolete on some parts of the body. A specimen of this type, 60 millimeters in diameter, was found in the upper part of the Liberty bed north of Canaan, Indiana. Much smaller specimens of the same general type occur 14 and 29 feet below the Brassfield or Clinton bed, in the Elkhorn bed, along Elkhorn creek, south of Richmond, Indiana. It is the extreme forms of this variety, without any indication of ridges, which here are figured as *Beatricea undulata-cylindrica.*

Beatricea undulata-cylindrica, var. nov.

(*Plate IX, Fig. 7.*)

In typical specimens of *Beatricea undulata* the vertical ridges and intervening grooves are at least sufficiently distinct to be

detected readily. Occasional specimens occur destitute of both ridges and nodes. These may be only extreme variants of *Beatricea undulata*, and here are figured as *Beatricea undulatacylindrica*.

Geological position. Four miles north of Richmond, Kentucky, half a mile north of Ophelia, in strata corresponding to the southern extension of the Liberty bed as exposed in Boyle, Casey, Marion, Washington, Nelson, and Bullitt counties. At Ophelia this smooth form of *Beatricea* is associated with *Beatricea undulata*, *Beatricea nodulosa*, *Labechia ohioensis*, *Columnaria alveolata*, *Calapœcia cribriformis*, *Streptelasmavagans*, *Platystrophia acutilirata*, and other fossils. Similar specimens have been found at the same horizon immediately west of Fredericktown, in Nelson county, and in the northeastern part of Raywick, in Marion county, Kentucky; also in the Elkhorn bed, along Elkhorn creek, south of Richmond, Indiana.

Beatricea nodulifera, sp. nov.

(*Plate VII, Fig. 13; Plate VIII, Fig. 5.*)

Cylindrical stems with nodes more or less irregular in arrangement, but tending toward arrangement in vertical rows with a slight spiral twist around the stem. In specimens in which this arrangement in vertical rows is most pronounced, some of the nodes are connected sufficiently to suggest vertical ridges separated by more or less irregular furrows. The lateral distance between these rows or ridges varies from 5 to 7 millimeters. In other specimens, the arrangement is more irregular. Specimens 50 millimeters in diameter have been collected, and the species is known to attain a larger size. The stems were several feet in length and grew in a vertical position, tapering slowly toward the top.

Geological position. The type specimens were obtained five feet below the base of the Devonian limestone, at a small falls a quarter of a mile south of the Sulphur Spring, three miles south east of Lebanon, Kentucky. Here *Columnaria* and *Tetradium* occur within three feet of the base of the Devonian limestone, and *Beatricea nodulifera*, *Beatricea undulata*, *Heterospongia subramosa*, and *Columnaria* occur two feet lower. This horizon is regarded as the base of the Liberty bed. Specimens have been found at the same horizon at Bardstown, Ky.

Beatricea nodulosa was described from the Ordovician at Wreck Point, Salmon River, and Battery Cliff, on Anticosti Island. The types appear to have been lost. A specimen from Battery Cliff, preserved in the Museum of the Geological Survey of Canada, owes its nodose character to a parasitic growth of *Labechia*. Judging from the specimens of *Beatricea* preserved in the Museum of the Canadian Survey, the nodes of *Beatricea nodulifera* are smaller and closer together. It will be necessary to collect specimens from the type localities in Anticosti in order to determine definitely how wide a range of variation is to be assigned to *Beatricea nodulosa*. For the present, the specimens here described as *Beatricea nodulifera* are regarded as distinct.

A specimen of *Beatricea*, found at Connersville, Indiana, was identified as *Beatricea nodulosa* by A. C. Benedict.

Beatricea nodulifera-intermedia, var. nov.

Plate VIII, Fig. 4, A, B, C.

Among the various aberrant forms of *Beatricea* found in Kentucky is one in which the nodes are considerably elongated, forming short ridges. The upper end of one of these short ridges frequently terminates slightly to the right or left of the lower end of one of the short ridges located farther up the stem, thus resulting in a vertical serial arrangement similar to that of *Beatricea nodulifera*. It is probably one of the extreme variants of that species.

Geological position. Near the base of the southern extension of the Liberty bed, in Marion county, Kentucky.

Brachiospongia lævis, sp. nov.

Plate VIII, Fig. 2.

In the specimen here figured the body has a horizontal diameter of about 75 millimeters, and a vertical diameter of 30 millimeters. However, since only one side of the body is well preserved, its original vertical diameter is unknown. The preserved sid is moderately convex toward the middle. It rested upon clay, and was partially imbedded at the time of discovery. It is assumed to have been the lower side of the body. If the upper side was occupied by a large osculum, no trace of the latter is preserved.

There are seven arms, approximately cylindrical at their bases horizontally flattened near the ends, but this flattening may have been due to crushing. There is no evidence of geniculate bending of the arms as in *Brachiospongia digitata*. The upper surface of the specimen, both in the region of the body and arms, contains numerous fragments of shells indicating either that the specimen was hollow, or that it consists only of an impression of the lower side of the original animal. The first view is favored at present.

Geological position. In the southern extension of the Mount Hope bed, about a mile north of Paint Lick, in Madison county, Kentucky At this point a road turns off westward from the Richmond pike and follows the northern side of a small stream entering Paint Lick creek. About 80 feet below the top of the section exposed along this road, *Strophomena maysvillensis* and *Constellaria florida* are very abundant. Below this is a series of argillaceous limestones interbedded with clay, about 30 feet thick, referred to the Mount Hope bed. This is the upper part of the Garrard sandstone of Marius R. Campbell. *Brachiospongia lævis* occurs two and a half feet above the base. The lower, massive part of the Garrard sandstone, regarded as the equivalent of the upper part of the Eden, equals at least 66 feet at this locality. To this lower part the name *Paint Lick bed* has been given.

In the Monograph on the *Brachiospongidæ*, Memoirs of Peabody Museum, volume 2, part 1, published in 1889, Prof. Charles E. Beecher published the following description of a specimen found in Spencer county, Kentucky:

A specimen of *Brachiospongia* found by W. M. Linney in the northern part of Spencer county, Kentucky, in strata of the Middle Hudson series, offers some points of difference with those from Franklin county. It is preserved in mudstone, and the parenchym of the sponge has been replaced by calcite. The specimen measures 235 millimeters in diameter, and has eight arms, which are constricted at their origin, directed outwards and downwards at an angle of forty-five degrees, and are not geniculated as in typical *Brachiospongia digitata*. The osculum is suborbicular, and the neck is campanulate below. The cup, or body, of the sponge is comparatively small. The base is flat, and without the initial projection usually present. Were it not for the great range of variation shown in the specimens from Franklin

county, it would seem that this form represented a distinct species. The differences are probably due to changed physical conditions.

The Middle Hudson strata of Linney are the stratigraphical equivalent of the Garrard sandstone of Campbell. The mudstone is an argillaceous limestone. The stratigraphical position of Linney's specimen and that here described as *Brachiospongia lævis* undoubtedly is the same. There is very little doubt as to the specific equivalency of the two specimens. From this it follows that *Brachiospongia lævis* has a suborbicular osculum, campanulate below. The number of arms probably varies as in *Brachiospongia digitata.* The absence of geniculation probably is a specific characteristic. The arms of the specimen from Madison county are much longer, but this may be due to better preservation.

Dystactospongia madisonensis, sp. nov.

(*Plate IX, Figs. 1, 5.*)

Sponge massive, irregularly lobate; the lobes in one specimen attain a length of 100 or more millimeters, with a diameter of about 40 millimeters. The surface of these lobes may be comparatively even or slightly nodose. Sometimes one of the lobes is traversed vertically by a broad groove, probably a case of incipient lobation. In the central parts of the sponge, the fibers appear to anastomose so as to produce an irregular net-work, but toward the surface a series of vertical passages results. These passages vary from 4 to 7 millimeters in length, are perpendicular to the surface, are about half a millimeter in diameter, and are separated by cœnenchym having about the same thickness. The openings at the surface are irregular, the larger ones frequently attaining a width of one millimeter, between which the smaller openings are interspersed. In the specimen from the vicinity of Versailles, oscula between 1.5 and 2 millimeters in diameter, and from 7 to 14 millimeters apart, are present. In other specimens, oscula were not noticed. In the specimen from Madison, this coarser sponge structure appears to be covered by a thin film without apertures but with numerous irregular elevations as in some specimens referred to *Labechia.* For the present this is regarded as a parasitic stromatoporoid growth.

Geological position. Lower part of the Saluda bed. Along

the Hanging Rock road, at Madison, Indiana, a specimen was found about 7 feet above the chief *Columnaria* bed, in sandy layers, associated with *Rhynchotrema capax*, *Strophomena sulcata* and *Streptelasma*. Two specimens were found a little over two miles south of Versailles, Indiana, opposite the home of Porter Harper, 65 feet below the base of the Clinton, immediately below the *Tetradium* horizon, in strata regarded as forming the base of the Saluda bed. Several specimens were found also a mile and a half northeast of Osgood, Indiana, in the lower part of the *Tetradium minus* bed, associated with numerous specimens of *Columnaria alveolata*, some of *Calapœcia cribriformis*, and the same forms of *Byssonychia* as those found in the *Tetradium* layer opposite the home of Porter Harper.

Heterospongia, sp.

(*Plate IX, Fig. 2.*)

The distinguishing features of *Heterospongia knotti* are the presence of oscula, scattered over the surface at intervals of 8 to 20 millimeters, and the relatively small apertures between the meshes of sponge fibers, about 6 to 8 in a length of 5 millimeters. These apertures tend to be rounded instead of roughly angular. In other respects this species closely resembles *Heterospongia subramosa*, a much more common species.

The specimen here figured appears to have poor indications of oscula and appears more closely related to *Heterospongia knotti* than to *Heterospongia subramosa*. It was found southeast of Lebanon, Kentucky. The types of *Heterospongia knotti* were found near Lebanon, Kentucky, but their exact horizon has not been determined. *Heterospongia* is found here both in the Liberty bed and in the upper part of the Maysville formation, in strata belonging below the *Dinorthis carleyi* horizon. All of the specimen found in situ belonged to the species *Heterospongia subramosa*.

Pasceolus darwini, Miller.

(*Plate VIII, Fig. 1, A, B.*)

Body spherical, consisting of a covering of polygonal plates, chiefly hexagonal, surrounding a body cavity at present filled with

argillaceous rock within which no structure has been discovered. The plates usually are not preserved, so that the fossil usually consists of a structureless globular mass with polygonal concave depressions locating the former position of the plates. The surface of the plates frequently is marked by radiating grooves extending from the central part toward the angles, near which they become indistinct. The fossils usually have a depressed globular form. This evidently is due to sagging, the fossil being preserved in a clayey matrix. The lower side frequently is indented by a broad shallow depression, which also may be due to pressure, but which for the present is regarded as diagnostic.

Geological position. At the base of the Bellevue bed, along the railroad two miles southeast of Maysville, Kentucky, in a layer of clay two feet thick, and in the immediately overlying limestone.

Specimens identified as *Pasceolus darwini* occur in the Valley school house railroad cut, between a mile and a half and two miles south of Lebanon, Ohio.

Specimens of *Pasceolus* retaining only the cavities left by the plates and resembling *Pasceolus darwini* occur a mile and a half northeast of Modest, Ohio, along a road crossing the direct road to Edenton, a short distance beyond Stone Lick creek, immediately above the *Platystrophia ponderosa* horizon near the middle of the Arnheim bed.

Astylospongia tumidus, James, appears to be identical with *Pasceolus darwini*. One of the best preserved specimens among the series of types preserved in the James collection in the Walker Museum at Chicago University shows a rather deep depression on the side usually regarded as the base. Several of these specimens show distinctly the stellate grooves on the surface of the polygonal plates. These specimens are labelled as coming from a level of 350 feet above low water in the Ohio river. Miller cites *Pasceolus darwini* from the hills back of Cincinnati at an elevation of about 400 feet above low water. From this it is evident that *Pasceolus* occurs at Cincinnati either in the Bellevue horizon or in the immediately underlying or overlying strata.

Pasceolus darwini agrees with *Pasceolus intermedius* in size of the body and in the size of the polygonal plates. The types of *Pasceolus intermedius*, Billings, are preserved in the Museum of the Geological Survey of Canada. Only the depressions left by the plates remain. The specimens are globular and vary from

25 to 28 millimeters in width. No depression was noticed on the basal surface. Four hexagonal plates occur in a width of 7 millimeters. The depressions left by the plates are concave as in *Pasceolus darwini*. The association of *Pasceolus intermedius* with a Silurian rather than Ordovician fauna suggests that when this species is better known it will prove distinct from *Pasceolus darwini*.

Streptelasma vagans, nom. nov.

(*Plate XI, Figs. 1, A, B, C.*)

The species of *Streptelasma* from the Richmond group of Ohio, Indiana, and Kentucky, long known as *Streptelasma corniculum*, has been referred more recently to *Streptelasma rusticum*, from the Hudson River group of Snake Island, in Lake St. John, in the province of Quebec, in Canada. Recently, L. M. Lambe has figured a specimen of *Streptelasma rusticum*, and, judging from his figures, this species is much more nearly cylindrical toward the top, and relatively more narrow than is true of the species characteristic of the Richmond of the region affected by the Cincinnati geanticline. *Streptelasma canadensis*, Billings, from the Hudson River group on Drummond Island, in Lake Huron, appears to have the inner edges of the septa more nearly vertical, producing a wider calyx, with a flatter bottom.

In the specimens from the Whitewater beds, at Dayton, Ohio, the corals more nearly resemble *Streptelasma canadensis* in form, but are less wide at the top. The number of primary septa is about 60 to 65. The secondary septa, approximately equal in number, do not extend more than one millimeter from the thickened walls of thc corals; frequently they appear not much more conspicuous than prominent striations. The calyx is conspicuously narrower at the base than near the top. In a specimen 25 millimeters wide at the top, the twisted central area at the base of the calyx equals about 8 millimeters in width, and the width of the base of the calyx, limited by the inner edges of the septa, does not exceed 10 millimeters. The free edges of the septa are not denticulated. While this species undoubtedly is closely related to *Streptelasma canadensis*, it is not regarded as identical.

Geological position. The type specimens are from the Whitewater bed at Dayton, Ohio. At this horizon they are abundant

in Ohio and Indiana. In the Liberty bed similar forms are common in Ohio and Indiana, and at the more northern localities in Kentucky. Southward, along the eastern side of the Cincinnati geanticline, at Wyoming, Owingsville, Howards Mill, it is confined to the base of the Liberty. The specimens found at the Merritt ferry, at the mouth of Red river, near College Hill, and Cobb Ferry, in Madison county, probably belong to about the same horizon. They occur at the base of the Liberty at Ophelia, north of Richmond. They occur in the Liberty bed also on the western side of the Cincinnati geanticline, as far south as Marion county. This may be the horizon also of the specimens found on Fishing creek, east of Somerset, in Pulaski county. In the upper or Blanchester division of the Waynesville bed *Streptelasma vagans* is common in Ohio, Indiana and northern Kentucky, although associated with *Streptelasma dispandum* which locally almost replaces the former species. Occasional specimens occur below the chief *Columnaria* layer, which forms the base of the Liberty bed, also in the vicinity of Bardstown, Kentucky. They are quite abundant at several horizons in the lower part of the middle or Clarksville division of the Waynesville bed in Clinton and neighboring counties, in Ohio. At Concord, Kentucky, they occur both 5 feet above and 5 feet below the *Strophomena concordensis* layer which there forms the base of the Waynesville bed.

Streptelasma insolitum, sp. nov.

(*Plate X, Fig. 3.*)

A small and relatively slender form of *Streptelasma* occurs occasionally in the Whitewater strata, along their southern edge of exposure, in Decatur, Jennings, and Ripley counties, in Indiana. The type specimen, from the Whitewater bed, a mile and a half southeast of Westport, on the east side of Painter creek, does not preserve the sides of the calyx, but the septæ leave a central area of only about 4 millimeters for the base of the calyx, the diameter of the coral at this level being 18 millimeters. A similar specimen was found at the same horizon about two and a quarter miles south of Versailles, opposite the home of Porter Harper.

Streptelasma dispandum, sp. nov.

(*Plate IX, Figs. 4, A, B.*)

In the Upper or Blanchester division of the Waynesville bed, along the creek southeast of the railroad station at Moores Hill, Indiana, a large robust form of *Streptelasma* occurs which differs from *Streptelasma vagans* chiefly in its more rapid rate of expansion. This is conspicuous especially in young specimens. When fully mature some of the largest specimens resemble *Streptelasma canadensis* in form much more closely than is true in case of typical specimens of *Streptelasma vagans*, from the Whitewater beds.

Geological position. Abundant in the Blanchester division of the Waynesville bed at Moores Hill, Indiana. Also, at the same horizon on the bluff east of Laughery creek, nearly a mile northeast of Versailles; along the creek, half a mile south of Olean; and along the creek, north of Canaan; all in Indiana. Specimens of the same type have been found at corresponding horizons in Ohio, but no attempt has been made to work out their geographical distribution.

Streptelasma divaricans, Nicholson.

(*Plate X, Figs. 4, A, B, C, D, E.*)

Streptelasma divaricans appears to be a small, sessile species, attached to shells or other objects. Usually two or three specimens are attached to the same shell, at about the same point, but sometimes more than a dozen may be found in the same cluster. The individual corals are inverted conical in shape. Where growing in clusters, the sides usually are more or less adnate, and may be deformed by pressure. The area of attachment usually is more or less oblique to the base, preserving the conical form of the coral on its free side. Occasionally a radicular expansion of the edges of the area of attachment is noticed. Specimens may be found in which the corallites are free at the top, but the presence of lateral gemmation has not been demonstrated in any specimens at hand.

Geological position. In the original description of this species one specimen is described as attached to the brachial valve of *Rhynchotrema dentata.* Although *Rhynchotrema dentata* occurs at

three horizons, in the upper part of the Whitewater bed, in the upper part of the Waynesville bed, and near the middle of the Arnheim bed, it is probable that the type of *Streptelasma divaricans* came from the Whitewater. *Streptelasma divaricans* is very common in the Whitewater bed in Ohio and Indiana, and occurs in Ohio, Indiana, and Kentucky in the Liberty bed, but *Rhynchotrema dentata* is very rare in the Liberty bed. A small sessile form of *Streptelasma* occurs in the upper or Blanchester division of the Waynesille bed at Versailles, Indiana, but it is rare at this horizon. In the Liberty bed *Streptelasma divaricans* it is found as far south as Bardstown, Kentucky. The most southern locality on the eastern side of the Cincinnati geanticline is at the Hornback curve, two miles west of Indian Fields, in Clark county. The horizon here appears to be a considerable distance above the base of the Liberty bed but the presence of the Whitewater bed has not been demonstrated as yet.

In the lower part of the Whitewater bed, a mile and a half southeast of Westport, Indiana, on the east side of Painter creek, a specimen of *Rafinesquina* was found to which 3 separate specimens of *Streptelasma divaricans* were attached, in each case so that all of one side was adnate to the shell. This appears to be only an extreme case of the oblique attachment often seen in specimens unequivocally identical with *Streptelasma divaricans*.

Streptelasma divaricans-angustatum, var. nov.

(*Plate IX, Fig. 6, A, B.*)

Several specimens of *Streptelasma divaricans* have been found in the Whitewater bed at Osgood, Indiana, which differ from the more typical examples of that species in having the sides less divergent. The form of the individual corals, therefore, is more nearly cylindrical. It appears to be a rare variant.

Protarea richmondensis, Fœrste.

(*Plate VII, Fig. 8.*)

The type of this species, here figured, is characterized by the presence of 12 distinct septa. It was found in the Whitewater beds, at Tate's hill, east of Dayton, Ohio. This form occurs at the same horizon at numerous localities in Ohio and Indiana,

In the Liberty beds it is common from Ohio and Indiana as far south as central Kentucky. It makes its first appearance in the upper part of the Middle or Clarksville division of the Waynesville bed, in Clinton and Warren counties, Ohio, and occurs also in the Upper or Blanchester division.

Typical specimens of *Protarea richmondensis* are associated with other specimens in which the septa are much less distinct. They appear to be replaced by papillæ, those along the margins of the calyces being larger, those at the base being smaller. At times these papillate specimens resemble growths of *Protarea richmondensis* covered by a thin film of the so-called *Stomatopora* or *Labechia papillata*. However, if this were the case, the so-called *Labechia papillata* should be common also on other fossils at the same localities, which is not the case. This papillate form of *Protarea* is illustrated by figures 9A and 9B, on plate V, in volume XIV of this Bulletin, and also on Plate X, figs. 2A, and 2B accompanying the present article.

The most southern locality at which *Protarea richmondensis* has been found is at Raywick, in Marion county. On the eastern side of the Cincinnati geanticline it has been found as far south as directly east of Wyoming, in the southwestern part of Fleming county. At both localities the horizon was the Liberty bed.

Protarea ? verneuili, Edwards and Haime.

(*Monographie des polypiers fossiles des Terrains Palæozoiques, 1851, p. 209.*)

Polypier en masse elevee, convexe; calices polygonaux, peu inegaux, separes par des murailles assez minces et presentant a leurs angles de petites colonnes greles: une vingtaine de cloisons peu inegales, assez minces; largeur des calices 3 millimetres.

Silurien inferieur. Alexanderville, Ohio.

Collection de Verneuil.

Unfortunately the type has been lost. This species is not a *Protarea*, that genus not possessing 20 septa. It scarcely could be a *Columnaria* since that genus was familar to Edwards and Haime and does not resemble *Protarea*. Moreover, the statement that the septa differed little in size and that the cell walls present at their angles some small slender columns scarcely agrees with *Columnaria*. As a matter of fact, however, some specimens of *Calapœcia* have a superficial resemblance to *Protarea*. The

septal lines of both are distinct at the mouth of the calices, and extend only a short distance from the walls, leaving circular spaces at the center, and both show traces of denticulate margins along the septa. The fact that the calices are described as polygonal need not disconcert the student since even Nicholson described *Calapœcia cribriformis* as having the corallites for the most part hexagonal or polygonal. Specimens of *Calapœcia* occasionally occur with calices fully 3 millimeters in diameter. Moreover, the base of the Liberty bed occurs at several localities within two or three miles of Alexanderville, and *Calapœcia* has been found at this horizon. It is my belief that if the type of *Protarea verneuilli* ever should be found it would turn out to be a *Calapœcia;* either that, or it is not an Ordovician species at all.

Calapœcia cribriformis, Nicholson.

(*Plate XI, Fig. 4.*)

Calapœcia cribriformis has cylindrical corallites which retain their cylindrical form owing to the fact that the walls of adjacent corallites are not in continuous contact as in genera of corals having polygonal corallites. The walls are penetrated by numerous mural pores arranged more or less in horizontal rows. The septal lines are distinct. In well preserved specimens their free edges are denticulate. The tabulæ usually are not well preserved or may be absent, but probably were present in all cases originally, since they are abundant, alternating with the horizontal rows of mural pores, in the various species of *Calapœcia* described by Billings.

Calapœcia cribriformis appears to be identical with *Calapœcia huronensis*, Billings, and the former name probably should be dropped, as acknowledged by Nicholson himself in later years.

Geological position. *Calapœcia cribriformis* is common at some localities west of the Cincinnati geanticline in the lower part of the Liberty bed, from Henry county as far south as Marion county, Kentucky. It occurs at the same horizon at Wyoming, Cobb Ferry and 4 miles north of Richmond, in Kentucky. In the lower part of the Saluda bed it occurs from Madison, Indiana, as far north as Osgood. Stray specimens occur in Indiana as far north as Richmond, and are known in Ohio at various localities in Clinton and adjacent counties. Near Clarksville, Ohio, speci-

mens have been found near the base of the Liberty bed. John Misener found two specimens at Richmond, Indiana; one in the Liberty bed; and the other in the upper part of the Whitewater bed.

Tetradium minus, Safford.

(*Plate X, Figs. 1, A. B.*)

This species is recognized readily by its small quadrangular corallites, breaking apart lengthwise so as to show an apparently fibrous structure. On close examination the presence of four septa, one attached near the middle line of each of the four walls, may be noticed. Additional septa may exist but require the use of a magnifier for detection.

Geological position. A species of *Tetradium* associated with the stromatoporoid usually called *Labechia ohioensis* occurs in the Fairmount bed on the Cumberland river, in Russell county, 2 miles east of Rowena, Kentucky. Small specimens are found 20 feet above river level, and larger specimens are found 35 feet above the river. The intervening rock contains *Orthorhynchula linneyi*. *Tetradium* and *Labechia* may be traced up the river as far as the exposures a quarter of a mile below Belk island. *Tetradium minus* occurs with the same association of fossils also in Maury county, Tennessee.

In the lower part of the Waynesville bed it occurs at Owingsville and Wyoming east of the Cincinnati geanticline and north of Mount Washington and west of Fisherville west of the geanticline. all in Kentucky. In Clinton county, Ohio, it makes its appearance in the *Orthoceras fosteri* horizon bed, at the base of the middle or Clarksville division of the Waynesville bed. East of Pendleton, Kentucky, and at the mouth of Bull creek, Indiana, it is common at a horizon which appears to be the upper part of the Waynesville bed. At the base of the Liberty bed it is quite abundant at many localities west of the Cincinnati geanticline, in Kentucky. The most southern localities are in Marion county, Kentucky. Occasional specimens are found in Indiana. On the eastern side of the geanticline it is much less common, but occasional specimens are found in the base of the Liberty bed as far south as Concord, Kentucky. It is possible that the specimens found at the Merritt ferry opposite the mouth of Red river, and several miles west of

Crab Orchard, east of Cedar creek, belong to the same horizon. It is an abundant fossil at the base of the Saluda bed in Jefferson and Ripley counties, in Indiana. At the top of the Saluda bed it occurs at numerous localities in Jefferson county, Indiana. In the Elkhorn bed it occurs both in Indiana and Ohio.

Columnaria alveolata, Goldfuss.

(*Plate XI, Fig. 3.*)

This species is readily distinguished in the region of the Cincinnati geanticline by its conspicuous septa, half of which almost or quite reach the center of the corallites.

Geological position. In the lower part of the Liberty bed this species may be traced from Jefferson county to the middle of Casey county, Kentucky. It occurs at the same horizon four miles north of Richmond and between Stanford and Crab Orchard. Large specimens occur half way between Peewee valley and Brownsboro, presumably at the same level. From Hanover and Madison, Indiana, as far north as the exposures two miles northeast of Osgood, they occur at the base of the Saluda bed, in some localities abundant, at others very rare. The specimens found by John Misener near the base of the exposures below Richmond, Indiana, probably came from the Liberty horizon. From the western part of Henry county, in Kentucky, to the northwestern edge of Nelson county, specimens also identified as *Columnaria alveolata* are common locally at one horizon in the lower part of the Waynesville bed. At Concord, Kentucky, specimens of *Columnaria alveolata* occurred not only at the base of the Liberty bed but one specimen was found also near the base of the Waynesville bed, associated with *Streptelasma vagans*, 5 feet above the *Strophomena concordensis* horizon. At Clifton, Tennessee, several specimens occurred in the Arnheim bed. *Columnaria alveolata* occurs near the base of the Liberty bed in Stony Hollow, northwest of Clarksville, Ohio. One specimen was found loose in the upper or Blanchester division of the Waynesville bed, at the Blacksmith Hollow northeast of the railroad station at Oregonia. Along Elkhorn creek, south of Richmond, Indiana, small specimens of *Columnaria alveolata*, associated with small specimens of *Columnaria vacua*, occur 14 feet below the Brassfield or Clinton bed, in the Elkhorn bed. Several poorly preserved

specimens of *Columnaria*, species not determined, are present in the lower part of the bluff on the west side of the Cumberland river, opposite the mouth of Forbush creek, in Wayne county, Kentucky, in strata regarded as of Richmond age.

Columnaria alveolata—calycina, Nicholson.

Columnaria calycina differs from *Columnaria alveolata* only in the tendency of a part of the corallites to become free and assume a more or less cylindrical shape. The corallites of this form also usually are a little smaller.

Geological position. This species was described from River Credit, Ontario, where it occurs in strata equivalent to the Richmond group. The same species was described by Rominger under the term *Columnaria herzeri*, and the statement was made that the types were found by Rev. H. Herzer, of Louisville, in the Cincinnati group, Kentucky. Specimens showing these features occur at the base of the Liberty bed north of Mount Washington, and from this point as far north as Jeffersontown, Kentucky. Their local distribution is the chief point of interest. They can be regarded as only a variety of *Columnaria alveolata.*

Columnaria vacua, sp. nov.

(*Plate XI, Fig. 2.*)

Associated with *Columnaria alveolata* in the great coral reef at the base of the Liberty bed in Jefferson, Bullitt, Nelson, and Marion counties, Kentucky, is a species in which the septa are represented by sharp striæ rather than strong plates. These striæ line the inner walls of the tubes, or corallites, and usually become indistinct at the margins of the horizontal diaphragms. In other respects this species is identical with *Columnaria alveolata.*

This species is listed by Nickles as *Columnaria halli*, Nicholson. The latter, however, is a smaller celled species from a much lower horizon. *Columnaria vacua* also frequently has been regarded as merely a different state of preservation of *Columnaria alveolata.* In that case, however, it is difficult to explain why the absence of conspicuous septa should be constant in large coral growths several feet in diameter, contiguous to others showing conspicuous septa, or why certain horizons should contain numerous

specimens of *Columnaria vacua,* while others, possessing the same geological features, several feet farther up, should contain chiefly *Columnaria alveolata.* The constancy of the same features throughout the corallum in the case of large specimens at numerous localities and at several horizons scarcely could be due merely to a different state of preservation.

Geological position. Base of Liberty bed, at Bardstown, Kentucky, and at numerous other localities at corresponding horizons in the counties mentioned above. At the base of the Liberty bed, this species may be traced from Jefferson to the center of Casey county. They occur at the same horizon 4 miles north of Richmond, and at various localities between Stanford and Crab Orchard. At the base of the Saluda bed they occur from Hanover and Madison, in Indiana, northward to the northern edge of Jefferson county. One specimen of *Columnaria,* referred to this species, was collected immediately above the *Hebertella insculpta* zone, at the base of the Liberty bed, at Concord, Kentucky. Near Clarksville, Ohio, one specimen was found 18 feet below the top of the Waynesville bed, in the Blanchester division. Along Roaring Run, in Warren county, Ohio, one specimen was found in the Liberty bed. Along Elkhorn creek, south of Richmond, Indiana, small specimens were found 15 feet below the Brassfield or Clinton bed.

Rhynchotrema inæquivalve, Castelnau.

(*Plate VII, Figs. 10, A, B, C.*)

This is the shell described by S. A. Miller in the *Cincinnati Quarterly Journal of Science* (vol. 2, p. 60, 1875) as *Trematospira quadriplicata* and later referred by him to *Rhynchotreta.*

Compared with *Rhynchotrema increbescens,* Hall, from the Trenton of New York, the beak of the pedicel valve appears more erect, the middle part of this valve is more flattened, and on lateral view the anterior parts of the brachial valve appear more obese. The radiating plications are less numerous and more prominent. The number of radiating plications on each side of the fold usually does not exceed five, and frequently is reduced to four. Of these the three nearest the fold are conspicuous, and the remaining one or two are much less distinct. The concentric striations frequently are rather distant, and present an imbricating effect.

· Typical *Rhynchotrema inæquivalve* belongs to the group having more numerous lateral plications, the middle parts of the pedicel valve are less flattened, and the beak is less erect.

Geological position. Common in the Paris bed wherever typically exposed in Kentucky. The most northern localities are at Drennan Springs and at Cynthiana. On South Benson creek, and at Frankfort, in Franklin county, it occurs also in the upper part of the beds containing *Prasopora simulatrix*, the characteristic fossil of the Wilmore bed.

Rhynchotrema manniensis, sp. nov.

(*Plate VII, Fig. 4.*)

Mature specimens of this species become full as gibbous as *Rhynchotrema capax*. In one specimen with a length and width of 14 millimeters, the gibbosity or extreme dimension perpendicular to the valves was 19 millimeters. This is a gibbosity in excess of that normal for *Rhynchotrema capax*. *Rhynchotrema manniensis* is a much smaller shell, it appears to be more compressed laterally, and has a greater number of lateral plications. Of these plications there are about 7 to 9 on each side of the median fold in case of the brachial valve. The sinus of the pedicel valve usually is narrower, relatively deeper in front, with more abrupt limiting slopes. As a matter of fact, however, the chief difference is one of size.

Geological position. In the Mannie shale, forming the upper part of the Richmond formation about three quarters of a mile west of Riverside, Tennessee; the exposure is located west of the home of Mr. Howard, on the road to Flat Woods, east of the mouth of Trace creek. It is found at the same horizon at Clifton, at the Maddox Mill on Horse creek, and also 32 miles northeast of Riverside, on Leiper's creek, a little over two miles south of Fly, north of the home of J. M. Gardner, all in Tennessee.

Leptæna gibbosa—invenusta, var. nov.

(*Plate VII, Fig. 3.*)

Width along the hinge-line about 30 millimeters; the postero-lateral parts of the shell being broken away, this width is an setimate. Fourteen millimeters from the beak, the anterior part of

the pedicel valve is geniculately deflected almost vertically for a distance of 6 millimeters. The general surface of this valve is gently convex. The concentric wrinkles characteristic of this genus are almost obsolete, the wrinkles being faint but close together. About 15 radiating striæ occur in a width of 5 millimeters along the anterior margin. The middle one of these striæ is slightly more prominent. The remainder are very uniform in size, and are separated by very narrow spaces.

Compared with *Leptæna gibbosa*, James, the shell material of each valve is thicker, the striæ are more nearly uniform in size, there is no concentric depression immediately posterior to the geniculate border, and this deflected border is shorter. Moreover, in *Leptæna gibbosa* the spaces between the striæ appear relatively wider, especially along the median parts of the pedicel valve.

Geological position. At the mouth of Emily run, 2 miles west of Drennan Springs, in a series of argillaceous limestones interbedded with greater quantities of clay. The total thickness of this clayey section is 18 feet. It is overlaid by coarse limestone, 2 feet thick, followed by the Southgate division of the Eden formation. Below the clayey section containing the *Leptæna* there occurs a series of limestones, 18 feet thick, overlying the typical Paris bed with *Rhynchotrema inæquivalve* and *Hebertella frankfortensis*. The top of the limestone section below the clayey beds containing *Leptæna* is characterized by a rather coarse limestone containing a *Hebertella* with rather more numerous plications than is typical of *Hebertella frankfortensis*. The argillaceous limestones and clay section within which the *Leptæna* was found is placed at the base of the Eden formation, but not necessarily in the Economy member, whose presence has not been demonstrated in the area in question. It may be an extension of the Fulton horizon.

A small specimen of *Leptæna*, 16 millimeters wide, with a distinct geniculate border, and with somewhat finer radiating striæ, was found in the clayey section overlying the massive argillaceous limestones in the railroad cut north of Boyd, Kentucky. The exact horizon was 11 feet above the massive limestone. It here is associated with *Trinucleus concentricus*, but the horizon may be an extension of the Fulton bed. The heavy limestones at the top of the hill section east of the cut probably correspond to the heavy

limestones in the Tunnel Cut east of Carlisle, Kentucky. A similar specimen of *Leptæna* was found north of Ford, Kentucky, about a quarter of a mile before reaching the second railroad tunnel, associated with *Clitambonites diversus-rogersensis*, *Plectorthis* (*Eridorthis*) *rogersensis*, *Plectorthis* (*Eridorthis*) *nicklesi*.

Strophomena vicina, sp. nov.

(*Plate VII, Figs. 12, A, B.*)

Shell closely related to *Strophomena planumbona*. The hinge-line usually is conspicuously longer than the width of the shell across the middle, producing an outline similar to that shown by that variety of *Strophomena planumbona* which was described by James as *Strophomena elongata*. However, the brachial valve does not attain as strong a convexity and the pedicel valve usually is only slightly concave, producing an appearance closely resembling those specimens of *Strophomena planoconvexa* which have a more elongated hinge-line. Compared with *Strophomena planoconvexa*, the radiating striations are much finer, equalling in this respect typical specimens of *Strophomena planumbona*. The muscular scars of the pedicel valve closely resemble those of the latter species, but the limiting border is much less conspicuously elevated. The vascular markings of this valve usually are faint or almost obsolete, although occasionally fairly distinct. There never is a strongly raised thickening of the shell along the anterior border interiorly. Frequently the margin of this part of the interior of this valve is striated in a radiate manner. The interior of the brachial valve closely resembles that of *Strophomena planumbona*.

Compared with *Strophomena trentonensis*, from the Trenton shales of Minnesota, the shell is larger, and the outline is more extended along the hinge-line, making it less quadrangular. The shell is not wrinkled obliquely along the hinge-line.

Geological position. In the upper part of the Paris bed along the road south of the Crow distillery, on Glen creek, in the northwestern part of Woodford county, associated with *Hebertella frankfortensis*, and immediately below a layer containing *Stromatocerium pustulosum*. In a blue, fine-grained limestone thirty feet below the highest beds containing an abundance of *Rhynchotrema inæquivalve*, in the southwestern part of Frankfort,

along the road passing the reservoir. In fine-grained limestone about 10 feet below a massive contorted layer and 25 feet above Benson creek, about a mile northwest of Bridgeport, along the road to Benson station. Along the railroad, about a mile west of Benson, associated with *Hebertella frankfortensis*, and immediately underlying argillaceous, fine-grained limestone, 11 feet thick. In the upper part of the Paris bed, on the C. H. Bowyer farm, northeast of Becknerville. At the top of the Paris bed or at the base of the Flanagan chert, at Flanagan. In the upper part of the Paris bed in the quarry in the northern part of Cynthiana. About 20 feet above the Ohio river, at Carnestown, Kentucky, in strata associated with *Eridotrypa mutabilis*, *Eridotrypa trentonensis*, *Prasopora falesi*, *Prasopora simulatrix*, *Callopora multitabulata*, *Dalmanella bassleri*, *Platystrophia* sp., *Plectambonites sericea*, and *Zygospira recurvirostra*.

Hebertella frankfortensis, James.

(*Plate VII, Figs. 11, A, B.*)

(*Catalogue of the Lower Silurian Fossils, Cincinnati Group, by U. P. James, 1871; p. 10, nomen nudum*).
(*Paleontology of Ohio, vol. 1, 1873; p. 101, under Orthis borealis.*)

Radiating plications usually simple, about 40 in number, occasionally increased by intercalation near the postero-lateral angles to forty-five. Hinge-line distinctly shorter than the greatest width of the shell; the latter is found either at or slightly anterior to the middle. Brachial valve almost evenly convex, the low, broad, median fold being almost imperceptible except when the shell is seen from the anterior side. The broad, shallow, median depression or sinus of the pedicel valve frequently is much more conspicuous, although in some specimens it scarcely amounts to more than a distinct flattening of the anterior part of the valve. This flattening usually does not extend nearer to the beak than one-third of the length of the shell. The hinge-area of the pedicel valve is slightly incurved, inclining outward, the beak rising distinctly above the level of that of the brachial valve. The largest specimens attain a width of one inch.

Compared with *Hebertella borealis*, Billings, from St. Martin's Junction, near Montreal, Canada, the flattening of the median parts of the pedicel valve begin nearer the beak and the shallow

median depression toward the anterior margin of the shell is a more constant feature. The result is a general flattening of the valve. The line of junction between the valves, when the latter are viewed from the front, is more sinuous. The brachial valve is never distinctly flattened or depressed anteriorly, but frequently is elevated slightly, so as to correspond with the more distinct median depression of the pedicel valve. The close relationship of this shell to *Hebertella borealis* is undoubted.

Geological position. Common in the Paris bed wherever typically exposed in Kentucky. The most northern localities occur at Drennan Springs in Henry county, and at Cynthiana in Harrison county. It occurs also in the underlying *Prasopora simulatrix* or Wilmore bed, but here it is much less abundant, or is even comparatively rare. The specimens here figured are from the Paris bed.

Hebertella maria—parksensis, var. nov.

(Plate VII, Figs. 6, A, B.)

A comparison of this form with the figures of *Hebertella maria* suggests that the chief difference consists in the larger size of *Hebertel a parksensis.* The latter frequently attains a width of 25 millimeters, and specimens 28 millimeters in width are not rare. The brachial valve is much more convex toward the beak, the umbo rising above the level of a plane passing perpendicular to the valve at its cardinal margin. A direct comparison with the types of *Hebertella maria* might show other differences.

Geological position. Abundant in the Greendale division of the Cynthiana formation between Pleasant Valley and Millersburg, Kentucky, associated with *Orthorhynchula linneyi.* The type specimens were obtained at Parks Hill, directly south of the Licking river, on the railroad between Maysville and Paris, Kentucky. Similar specimens but in much smaller numbers occur as far south as the middle of Madison county, and westward as far as Woodford county. In the northwestern corner of Woodford county, one mile southeast of McKee's Ferry, *Hebertella maria-parksensis* occurs in the Perryville bed, associated with *Orthorhynchula linneyi,* 7 feet above the Paris bed containing *Hebertella frankfortensis* and a species of *Columnaria.*

Dinorthis ulrichi, sp. nov.

(*Plate VII, Figs. 7, A, B, C.*)

This species closely resembles *Dinorthis subquadrata* in almost every feature, exterior and interior. *Dinorthis ulrichi* differs chiefly in the more conspicuous flattening of the pedicel valve, the convexity at the umbo being less prominent and being confined to the immediate vicinity of the beak. In some specimens the median part of the valve is depressed anteriorly so as to form a broad, shallow sinus. The shell frequently is wider posteriorly than across the middle, producing a more angular outline, posterolaterally, than in most specimens of *Dinorthis subquadrata.* The radiating plications usually are coarser than in that species, but individual specimens may be selected which do not differ in this respect. The muscular impressions of the pedicel valve are similar in form but tend to be relatively smaller in size, occupying slightly less than half the length of the valve.

Compared with *Dinorthis meedsi*, Winchell and Schuchert, *Dinorthis ulrichi* is much larger, the pedicel valve is more strongly flattened, the shell is less suborbicular in outline, and the plications usually are coarser.

Geological position. The types are from the upper part of the Paris bed on the C. H. Bowyer farm, northeast of Becknerville, in the western part of Clark county, Kentucky. The exposures are on the eastern side of the creek crossing the farm in a southerly direction. The Flanagan chert is exposed west of the creek toward the northern part of the farm. Associated in the same layers with *Dinorthis ulrichi* are *Hebertella frankfortensis*, *Rhynchotrema inæquivalve*, and *Strophomena vicina.* It is found at the same geological horizon, also at Flanagan, in Clark county, and in the railroad cut in the northeastern part of Paris, in Bourbon county, Kentucky.

Dinorthis carleyi—insolens, var. nov.

(*Plate VII, Fig. 9.*)

A variety of *Dinorthis carleyi* occurs at various localities in Ohio and Indiana at the base of the Upper or Blanchester division of the Waynesville bed which differs from the typical form of the species only in having somewhat wider and flatter plications.

Geological position. The specimen here figured was obtained about 2 miles northwest of Miltonville, Ohio, east of the Blankenbecker farm, along Dry Fork of Elk Run, a short distance above the lower *Hebertella insculpta* zone. This lower *Hebertella insculpta* zone marks the base of the Waynesville bed from the neighborhood of Miltonville as far toward the southeast as the southern part of Adams county. *Dinorthis carleyi-insolens* has been found along this line at the crossing of the road from Middleboro to Oregonia, two miles east of Hammel, in Warren county. It occurs in the Stony Hollow northwest of Clarksville, and on Sewell's Run, southeast of Clarksville; also about a mile northwest of Blanchester; all in Clinton county. It is found also southwest of Woodville, in the northeastern part of Clermont county. A single specimen, not in situ but at the lower part of the Blanchester division was found about two miles southwest of Oxford, Ohio. In Indiana, the same variety occurs at the base of the Blanchester division, but without the presence of *Hebertella insculpta*, on the east side of Blue creek, west of Blue creek post office; at the home of Nick Senefeld, four miles south of Brookville; at the home of William Bauman, three miles southwest of Brookville; and also in Union county, opposite the home of Robert Martin, half a mile above the mouth of Silver creek.

Dalmanella emacerata, Hall.

(*Plate VII, Fig. 1.*)

In the original description of this species by Hall no clue is given as to the horizon at which the type specimens were found beyond the fact that they occurred in the shales of the Hudson river group near Cincinnati, Ohio. Usually, at that time, the term *shales* was applied by preference to the Eden beds. Later, S. A. Miller identified with this species a form found 160 feet above low water in the Ohio river, at Columbia avenue and Torence road, and in the excavation of Deer creek tunnel. The specimens from this Middle Eden horizon were figured in volume XIV of this Bulletin as *Dalmanella emacerata-filosa* (fig. 1, plate V). In these specimens, the radiating striations appear more numerous than in the types of *Dalmanella emacerata*, preserved in the American Museum of Natural History, in New York city.

The specimens most nearly conforming to the first published

figure of *Dalmanella emacerata*, namely figure 1 on plate 2 of the Fifteenth Report, New York State Cabinet of Natural History, appear to be those which were obtained from the Fulton or *Triarthrus becki* horizon, at Cincinnati, Ohio. Considering the fact that the so-called River quarries were largely operated at the time when the earlier collections were made at Cincinnati, this identification is not improbable. In favor of this identification is the coarseness of the radiating striæ; evidently distinctly greater than that of the specimen represented by figure 2 on the same plate. A specimen from the Fulton bed is figured in the present number of this Bulletin.

As a matter of fact, the type specimen of *Dalmanella emacerata*, preserved in the American Museum of Natural History, appears to be not quite as coarsely striated as these Fulton specimens, or as the first published figure.

Dalmanella breviculus, Fœrste.

(*Plate VII, Fig. 5.*)

This form would not be considered distinct from *Dalmanella emacerata-filosa*, were it not for the fact that intermediate forms are unknown at present. The shorter length, resulting in a semicircular, rather than subquadrate outline, is the chief distinguishing feature. See figure 2 on plate 2 of the *Fifteenth Report*, New York State Cabinet of Natural History.

Geological position. Middle Eden beds at Cincinnati, Ohio.

Dalmanella fairmountensis, Fœrste.

(*Plate VII, Fig. 2.*)

An enlarged figure of one of the type specimens is presented in this Bulletin, for purposes of comparison with the enlarged figures of the other forms belonging to the *Dalmanella emacerata* group.

Geological position. Fairmount bed, at Hamilton, Ohio. Found also at Cincinnati, Ohio, New Trenton, Indiana, and along the Baltimore and Ohio Southwestern railroad, half a mile east of Dillsboro station, in Indiana, at the same horizon.

Clitambonites diversus—rogersensis, var. nov.

(*Plate VII, Figs. 14, A, B.*)

This is an extremely variable species and it is difficult to determine from the specimens at hand whether it is to be regarded as identical with *Clitambonites diversus*, Shaler, or as new. The pedicel valves vary between forms which are quite symmetrical in shape, and which appear to predominate, to others in which not only the beak is excentric, but the entire valve is more or less irregularly contorted. The area of this valve is broadly triangular and varies from 7 to 8 millimeters in height; it usually forms an angle of about 100 to 115 degrees with the plane of junction of the valves, but may be inclined forward so as to form an angle of 70 degrees. The brachial valve is flat, with a broad, shallow, median depression anteriorly. The most conspicuous feature of this valve is its great width, considering its length. Several specimens 24 millimeters wide had a length of only 14 or 15 millimeters. In these specimens, the posterior adductor scars and the depressions between the cardinal process and the crural plates are considerably shorter from front to rear than in the Trenton specimens of *Clitambonites verneuili*, Billings. The anterior adductor impressions are distinctly indicated and either equal or exceed in size the posterior ones. The number of radiating striæ varies from 4 to 5 in a width of 3 millimeters.

Geological position. In the lower part of the Eden formation at Rogers Gap and also north of Ford, a quarter of a mile before reaching the second tunnel, Kentucky, associated with *Plectorthis (Eridorthis) nicklesi*, *Plectorthis (Eridorthis) rogersensis*, and a *Leptæna* similar to that found at Boyd, Kentucky.

Smaller specimens of *Clitambonites*, apparently belonging to the same variety as the preceding, occur in the coarse-grained limestone quarried about a mile and a quarter west of Carlisle, and in contorted fine-grained argillaceous limestone exposed east of Carlisle, both before reaching the so-called Tunnel cut, along the railroad, and also at the exposures immediately beyond the cut. At the latter locality the following section is seen, described in descending order:

Hard blue limestone layers, cross-bedded	4 ft.
Hard limestone with a nodular base	2 ft. 3 in.
Nodular argillaceous limestone with *Clitambonites*	3 ft. 4 in.

Solid blue limestone layer..1 ft. 2 in.
Nodular argillaceous limestone with *Clitambonites*....................6 ft. 6 in.
Thin limestone layers interbedded with a greater quantity of clay, not
measured, approximately...40 ft.
Top of Cynthiana formation.

The clays overlying the Cynthiana formation carry an extension of the Fulton fauna. The extensive exposures at the Tunnel cut overlie the *Clitambonites* horizon. The relation between the *Clitambonites* horizon at Carlisle and that at Rogers Gap has not been determined.

PLATE VII.

Fig. 1. *Dalmanella emacerata*. Cincinnati, Ohio, from the Fulton bed. Magnified 1.6 diameters.

Fig. 2. *Dalmanella fairmountensis*. Hamilton, Ohio. Fairmount bed. Magnified 1.6 diameters.

Fig. 3. *Leptæna gibbosa-invenusta*. Two miles west of Drennan Springs, Kentucky. In strata underlying the Southgate member of the Eden; possibly an extension of the Fulton bed. Magnified 1.6 diameters.

Fig. 4. *Rhynchotrema manniensis*. Three quarters of a mile west of Riverside, Tennessee, in the upper part of the Richmond formation.

Fig. 5. *Dalmanella breviculus*. Cincinnati, Ohio. Southgate bed. Magnified 1.6 diameters.

Fig. 6. *Herbertella maria-parksensis*. Parks Hill, Nicholas county, Kentucky. Greendale member of the Cynthiana formation. A, brachial valve. *B*, pedicel valve.

Fig. 7. *Dinorthis ulrichi*. A, brachial valve. *B*, *C*, pedicel valves. Northeast of Becknerville, Kentucky. Paris bed.

Fig. 8. *Protarea richmondensis*. Figure of the type, enlarged 1.6 diameters. Dayton, Ohio. Whitewater bed.

Fig. 9. *Dinorthis carleyi-insolens*. Northwest of Miltonville, Ohio, in the Blanchester division of the Waynesville bed.

Fig. 10. *Rhynchotrema inæquivalve*. Lexington, Kentucky. Paris bed. This is the form described by S. A. Miller as *Trematospira quadriplicata*. *A*, lateral view. *B*, pedicel valve. *C*, brachial valve.

Fig. 11. *Hebertella frankfortensis*. *A*, pedicel valve. *B*, brachial valve. Lexington, Kentucky. Paris bed.

Fig. 12. *Strophomena vicina*. Pedicel valves. Northeast of Becknerville, Kentucky. Paris bed.

Fig. 13. *Beatricea nodulifera*. Three miles southeast of Lebanon, Kentucky. Near the base of the Liberty bed.

Fig. 14. *Clitambonites diversus-rogersensis*. *A*, pedicel valve. *B*, interior of brachial valve. Rogers Gap, Kentucky. In the strata underlying the Southgate member of the Eden formation, but including *Eridorthis rogersensis* and *E. nicklesi*, and carrying a fauna differing from that of the Economy member.

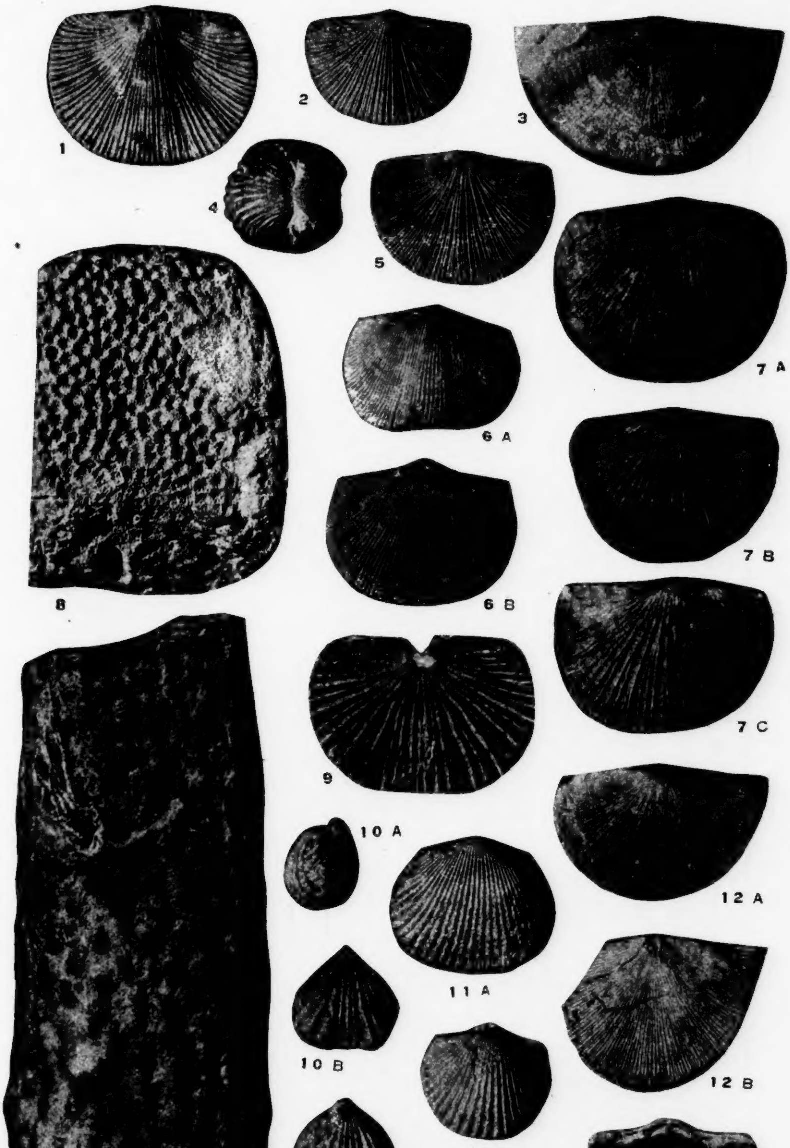

1
2
3
4
5
6 A
6 B
7 A
7 B
7 C
8
9
10 A
10 B
10 C
11 A
11 B
12 A
12 B
13
14 A
14 B

PLATE VIII.

Fig. 1. *Pasceolus darwini.* *A*, *B*, different specimens. Two miles south of Maysville, Kentucky, along the railroad. At the base of the Bellevue bed.

Fig. 2. *Brachiospongia lævis.* Figure reduced to half size. One mile north of Paint Lick, Kentucky. Near base of Mount Hope bed.

Fig. 3. *Beatricea undulata.* Bardstown, Kentucky. In the lower part of the Liberty bed.

Fig. 4. *Beatricea nodulifera-intermedia.* *A*, lateral view. *B*, terminal view of the same specimen, showing the central area occupied by large convex diaphragms, and the general mass occupied by numerous cystoid plates. Lebanon, Kentucky. Near the base of the Liberty bed.

Fig. 5. *Beatricea nodulifera.* Lebanon, Kentucky. Near the base of the Liberty bed.

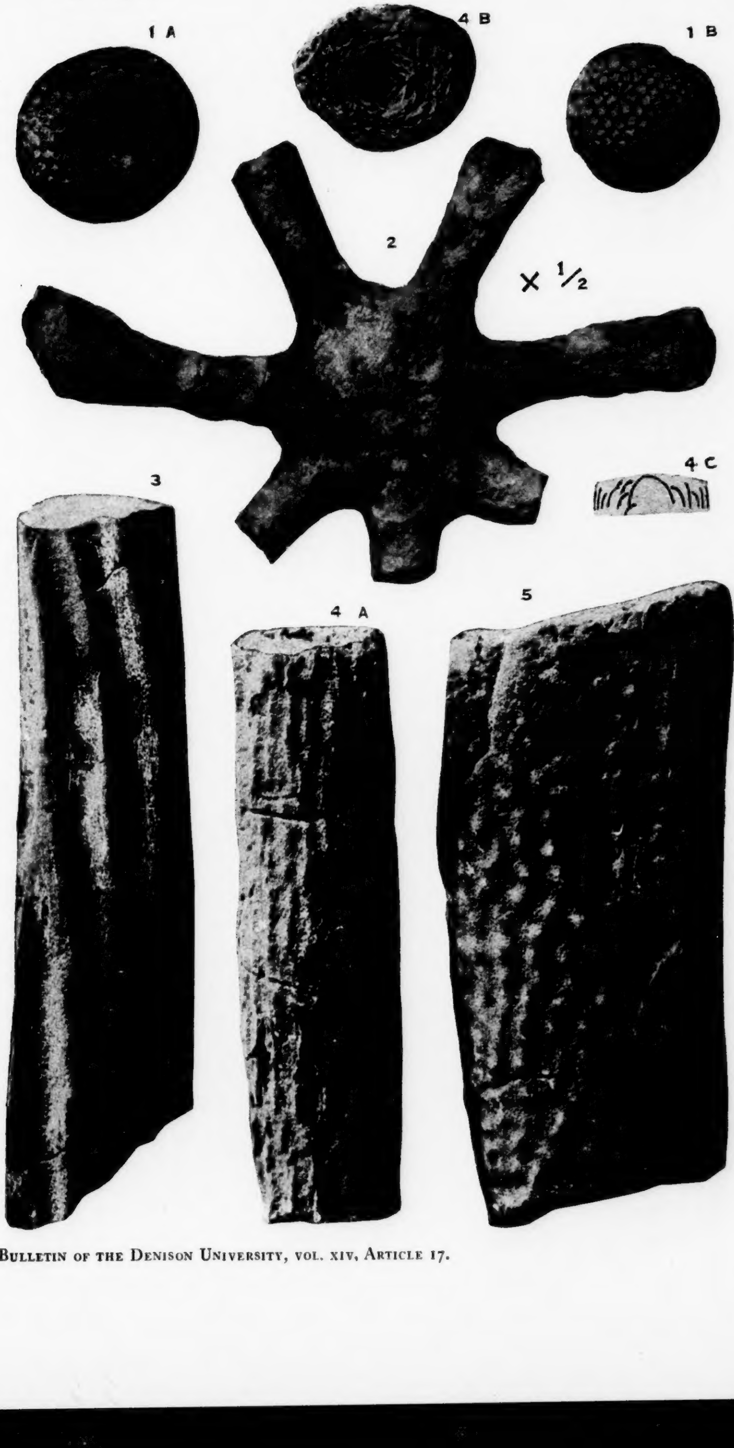

1 A
4 B
1 B
2
× 1/2
4 C
3
4 A
5

PLATE IX.

Fig. 1. *Dystactospongia madisonensis*. Madison, Indiana. Saluda bed, 7 feet above the chief *Columnaria* layer.

Fig. 2. *Heterospongia*, probably *H. knotti*. A mile and a half southeast of Lebanon, Kentucky. In the upper part of the Maysville formation below the Arnheim horizon.

Fig. 3. *Streptelasma*, apparently an aberrant form of *Streptelasma vagans*. Dayton, Ohio. Whitewater bed.

Fig. 4. *Streptelasma dispandum*. Moores Hill, Indiana. In the Upper or Blanchester division of the Waynesville bed.

Fig. 5. *Dystactospongia madisonensis*. A little over two miles south of Versailles, Indiana. Part of the surface of a lobate form, similar to that represented by figure 1. At the base of the Saluda bed, immediately beneath the *Tetradium* horizon.

Fig. 6. *Streptelasma divaricans-angustatum*. Osgood, Indiana. Whitewater bed.

Fig. 7. *Beatricea undulata-cylindrica*. Four miles north of Richmond, Kentucky. Liberty bed.


1
2
3
4 A
4 B
5
6 A
6 B
7

PLATE X.

Fig. 1. *Tetradium minus*, Safford. *A*, natural size. *B*, cross-section enlarged; copied. Mouth of Bull creek, Indiana. Richmond group.

Fig. 2. *Protarea richmondensis-papillata*. *A*, natural size. *B*, a part of the same specimen, enlarged. Encrusting *Strophomena planumbona*. Dayton, Ohio. Whitewater bed.

Fig. 3. *Streptelasma insolitum*. Walls of calyx broken off. A mile and a half southeast of Westport, Indiana. Whitewater bed.

Fig. 4. *Streptelasma divaricans*, Nicholson. *A*, the calyx of one specimen. *B*, the same, enlarged. *C*, *D*, lateral views showing calyces. *E*, a group viewed from above. Osgood, Indiana. Whitewater bed.

Fig. 5. *Brachiospongia tuberculata*, James. *A*, view of lower surface. *B*, lateral view. Both views reduced in size. The greatest dimension is 235 mm. Seven miles west of Wilmington, Ohio, south of the road from Ogden to Vandevorts Corner, along one of the branches entering Todds Fork from the west. Liberty bed.

ORDOVICIAN FOSSILS. PLATE X.

A. F. Foerste.

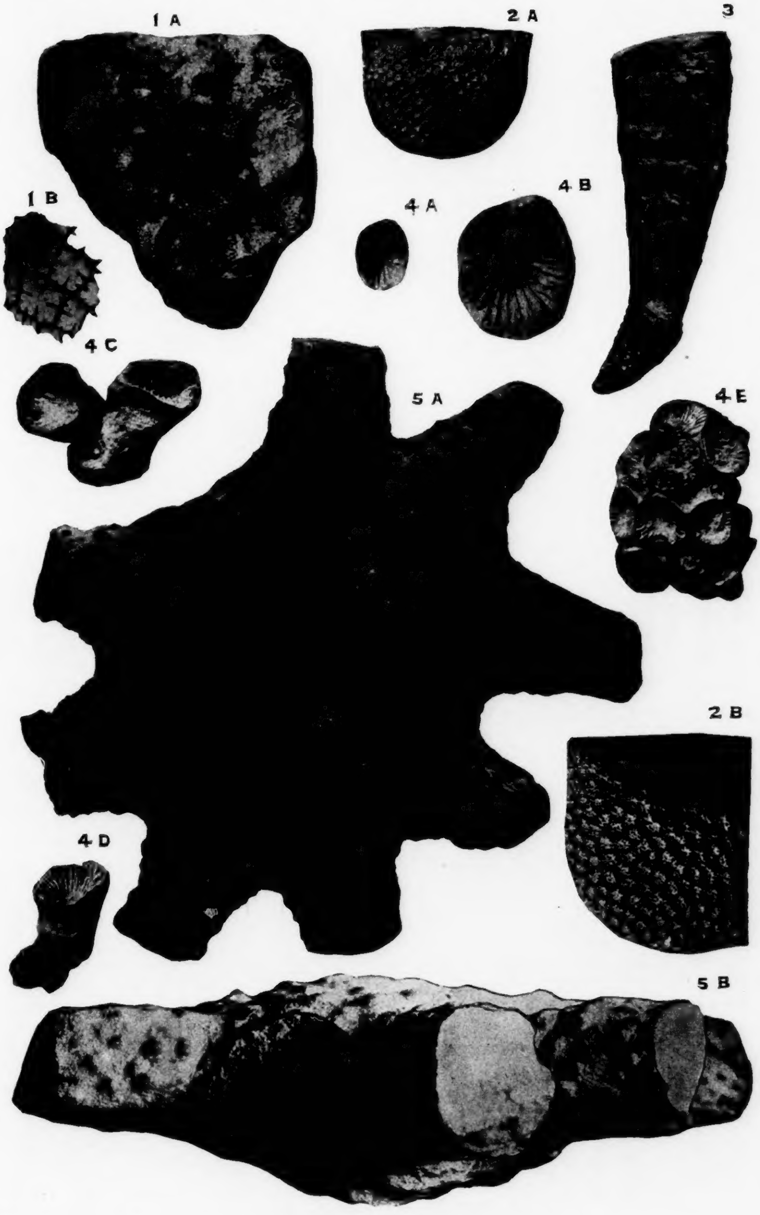


PLATE XI.

Fig. 1. *Streptelasma vagans.* *A*, lateral view, showing interior of calyx. *B*, lateral view. *C*, view from above, the sides of the calyx having been broken away, showing the twisting of the septa at the center. Dayton, Ohio. Whitewater bed.

Fig. 2. *Columnaria vacua.* Bardstown, Kentucky. At the base of the Liberty bed.

Fig. 3. *Columnaria alveolata*, Goldfuss. Bardstown, Kentucky. At the base of the Liberty bed.

Fig. 4. *Calapœcia cribriformis*, Nicholson. Bardstown, Kentucky. Near the base of the Liberty bed.

1 A

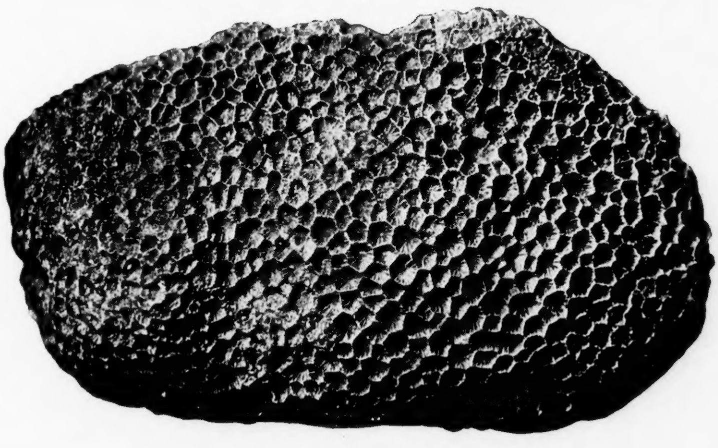
1 B

1 C

2

4

3



PLEISTOCENE GEOLOGY OF THE MORAVIA QUADRANGLE, NEW YORK.

By Frank Carney.

CONTENTS.

Physiography of the Moravia Sheet.

STRATIGRAPHY.

The rocks outcropping in this region belong to the Devonian Period, representing the formations from the Hamilton to the Portage inclusive. The higher areas bear the Portage which contains many arenaceous layers interspersing the sandy shale. The Genesee is best exposed about Montville and in the gorge of Dry Run. The Tully limestone has been cut by the Owasco Inlet valley, and may be studied to advantage along the eastern wall from a point about one mile north of Moravia southward nearly to Locke. Fig. 6 gives the contact of the Hamilton and Tully, also of the Tully and Genesee at the falls in Dry Run.

These formations disintegrate readily. The Portage contains no very heavy beds. The Tully, as shown by fig. 6, consists of several beds. This formation resists weathering better than the others, but its slight thickness, nowhere more than fifteen feet, does not enable it to form much of a shoulder or cliff on the valley wall.

THE SEVERAL CLASSES OF VALLEYS.

The valleys of this area appear to fall into four classes: (1) Those of greatest maturity; (2) those of a more recent cycle; (3) those of inter-glacial development; (4) those of post-glacial carving.

(1) *Those of Greatest Maturity:* Of the oldest valleys in the quadrangle Fall Creek is the most typical (fig. 2). The valley of this creek heads near the north margin of the quadrangle (fig. 1), possibly a little north in the Skaneateles sheet. Its exact origin is somewhat indefinite because of burial by glacial drift. The valley, however, opens towards the south and in the vicinity of McLean joins a wider valley which leads from Cortland, trending southwestward towards Ithaca. The valley of Fall Creek apparently is in topographic adjustment with this wider valley. There are also certain mature tributaries of the former valley, particularly one which heads north from Summer Hill joining the major valley south of Groton City. Other arms of equal maturity (fig. 3) may be observed.

To this same drainage cycle perhaps belong the wide contours which represent a former valley leading southwestward from

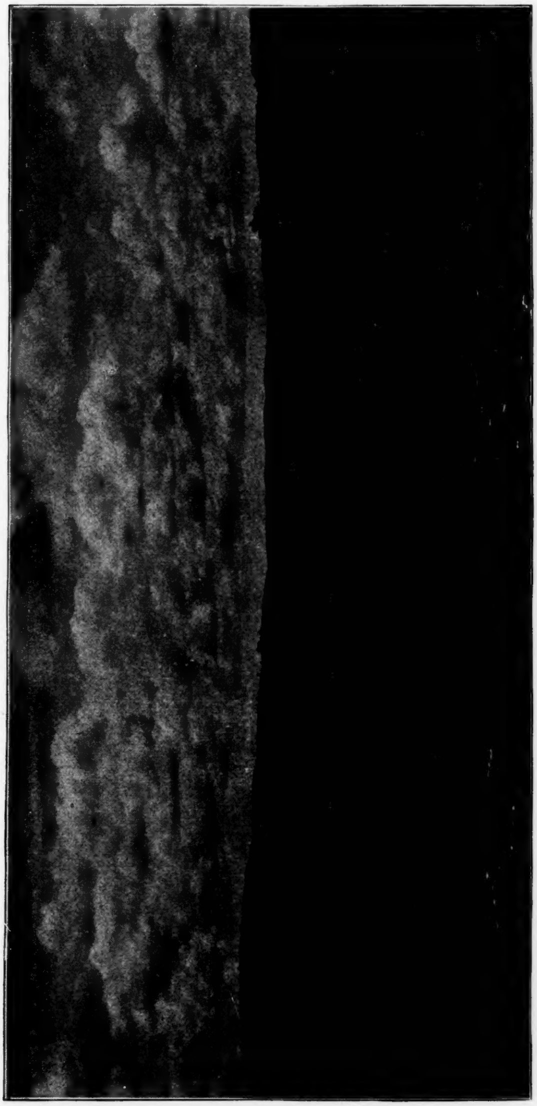


Fig. 1. Looking south through Fall Creek valley. Camera stands near high-way just east of the headwater area of Bear Swamp creek. The most distant hills lie east of Dryden.

Locke. We may call this the North Lansing-Locke valley; it has a genetic relation to Salmon Creek valley of the Genoa quadrangle, the first one west.

Possibly of the same age is the valley extending eastward, with a tributary northward, from Montville. In this connection it may be suggested that the erosion slope of the area southeast of Moravia and east of Montville indicate that the maturity about Montville possibly has a genetic association with the work of the Locke-North Lansing stream.

(2) *Those of More Recent Cycle.* Belonging to a cycle perhaps next younger than the one just described are the valleys of Skaneateles Inlet and, in parts at least, that of the Owasco Inlet. Only a segment of the Skaneateles Inlet (fig. 5) is included in this sheet, in the northeast corner. Glacial erosion has markedly altered the cross-section of these valleys as now they are in places walled by steep rock slopes; but a study of their cross-sections above the U-part of glacial erosion origin shows that they are less mature than the drainage lines considered in the preceding section.

The Owasco valley southward from Moravia to the vicinity of Peruville bears several loops of moraine and a few areas of wider morainic bands. From the study given the region it is apparent that the rock boundaries of the valley narrow about two miles north of Groton; there must have been a former divide here for there is no stratigraphic cause for the narrowing. On this supposition, the drainage which now controls this narrow area indicates a more recent period of erosion.

(3) *Those of Inter-glacial Development.* The evidence of inter-glacial erosion on this sheet is very plain in a few localities, and probably more detailed work would discover other examples; my study of the sheet has given this matter only incidental attention.

The valley in which Montville lies hangs about 200 feet above the flood plain of Owasco Inlet valley; at the southwest corner of Main and Walnut streets in Moravia a well 200 feet deep does not reach rock, so the height of the hanging is at least 400 feet. The mouth of this lateral valley has not just a single channel through which its drainage has been let down into the controlling valley; but even the contour lines show evidence of two such channels; and there is strong evidence of a third apparently buried by the massive delta gravels to the north. The road from Moravia to

Montville by way of the flour mill has for a short distance a sharp grade up over the south wall of the present stream, then relatively a gentle grade the rest of the way; this latter part of the course is a deserted channel. While I have not attempted a final study of these channels, one hypothesis is as follows: The stream is now following, in part of the course from Montville, an inter-glacial route which came into use again early in the post-Wisconsin interval by a minor tributary gradually working its way back from the floodplain at Moravia, removing the delta gravels, etc., till it captured the drainage that had been flowing through the channel now deserted. That this channel, now followed by a highway, is of post-Wisconsin origin is believed because it contains neither till nor delta gravels; it is possible that stream work since the last ice-invasion has disclosed a channel carved earlier, but not very probable.

About one mile south of Moravia is Dry Run, which rises near Lickville. For a mile in the lower part of its course this stream occupies a narrow rock-walled gorge; up-stream, the valley is more mature. Just south of the gorge segment is a wider, partly buried, rock-walled channel now occupied by a slight creek; the highway runs near this deserted course which has several characteristics indicating inter-glacial origin. This latter channel appears to correlate with the wider part of Dry Run valley, but no attempts were made to trace the buried portion.

(4) *Those of Post-Glacial Carving.* All the present gorge-cutting on this quadrangle is but a continuity of erosion that has been in force since the withdrawal of the Wisconsin ice. Along the Moravia Inlet valley, commencing at the Freeville end, we find the first of these post-glacial gorges at Peruville. This is a short and rather shallow gorge in the lower formations of the Chemung rocks. It is very probable that much of this gorge-cutting work here represented was accomplished even while the ice was near at hand. The torrential aspect of the stream is evidenced by the existing alluvial fan that is built out into the main valley at Peruville, a fan that is out of proportion to the drainage area controlled by this stream. Therefore the suggestion that the fan and the gorge represent abnormal drainage conditions.

Proceeding northward through the inlet valley the side walls are so deeply buried beneath glacial drift, and the catchment basins of the creeks so limited, that post-Wisconsin time has but

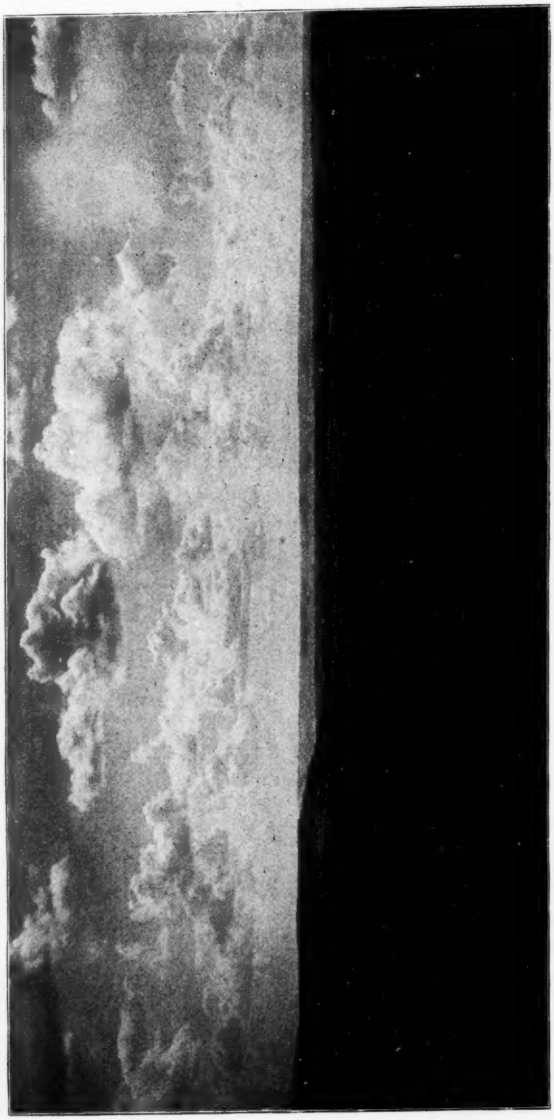


Fig. 2. Looking slightly south of west from top of the 1810-foot hill east of Freeville. Shows shape of the lower Fall Creek valley, position of the Cayuga trough, also the Seneca-Cayuga divide. The wooded and cloud-shaded area on right center marks position of the George Junior Republic grounds.

rarely sufficed to remove the drift sufficiently for much rock-cutting, so that there are no post-glacial gorges, though there are many sags or small valleys representing post-glacial stream erosion. Near Groton on the east side of the valley two streams for short distances are on rock, but this is nearly a mile from the floor of the main valley. North of Centerville we find the gorge of Dry Run (fig. 6), already alluded to. On the west slope of the Owasco valley we would anticipate many glens, since the steep fall should encourage rapid erosion, but the creeks have such limited catchment basins that they have been unable to produce any marked channels in the slopes.

At Montville the stream coming from the north flows in the last mile or so of its course, between rock walls. This stream has a fall of fifteen to twenty feet over the Tully limestone, which forms a conspicuous shoulder and is easily quarried along the east wall of the valley as far south as Locke; and a short distance down stream a slightly greater fall over hard layers in the underlying shale, the latter fall being used by the village of Moravia in connection with its electrical plant.

Northwest of Lake Como is a slight post-glacial gorge cut in some of the harder layers of the Portage sandstone. The small basin of this stream is apparently all out of proportion to the gorge-cutting here present. The explanation of the condition, however, is apparent as one follows the highway toward North Summer Hill. Just east of this village, at about the head of the valley whose gorge we are describing, is found a loop of moraine (p. 366) marking a position where the ice stood for some time. The gorge-cutting was done when the valley was carrying a burden of ice-front drainage.

About a mile east of Sempronius one passes between rock walls in following the highway into the Skaneateles valley. These rock walls cannot be connected genetically with present drainage; nor, from deductions that one would make, has the former development of drainage in the area developed the gorge. The only reasonable hypothesis for the gorge cutting here represented is that the erosion was done by ice-front waters, and this supposition is sustained by the nature of the channel which leads into the head of this rock gorge from the north (p. 432).

In the southwestern part of the quadrangle near Asbury is another gorge which presumably represents the work of post-

Fig. 3. Southeast of McLean is a tributary valley of Fall Creek, which heads in Cortland county. This view looks along the axis of this tributary valley, showing its flattened cross-section as well as the maturity of the major valley.

Fig. 4. Looking east across the Owasco valley at Locke; camera stands near the 1200-foot contour. Valley drift shows on both slopes.

Wisconsin waters. This gorge continues westward into the Genoa quadrangle.

In the discussion of post-Wisconsin carving it is apparent that no sharp distinction has been made between the work of immediately ice-front waters and the erosion-work of more recent streams. In all cases, except the downhill gorges associated with the glacially steepened valley walls, and the channels connected with the Skaneateles Inlet, both factors probably enter somewhat into the gorge-cutting. The Skaneateles Inlet channel, however, is purely the work of an ice-front stream.

Fig. 5. Looking north through Skaneateles Inlet valley; camera stands near mouth of overflow channel. Small portion of lake shows in middle of picture; the heavily wooded slope paralleling eastern shore marks the upper limit of more vigorous ice-erosion.

PRESENT POSITION IN DRAINAGE CYCLE.

Aside from a few post-glacial streams now in rock there is very little degradational work being done at the present time in the area of this quadrangle. Streams of this type have a local base-level due either to glacial overdeepening of the main drainage

lines of which they are tributaries, or to the work of an abnormal quantity of water which their valleys carried in immediate post-glacial times. Such channels, where topographic adjustment is in progress, exist at Peruville, a few between Locke and Moravia, at Montville, and in the short tributary valley south of Dresserville.

The base-level of the present Owasco Inlet valley is Owasco lake, which is 464 feet above the level of Lake Ontario. The base-level represented by Lake Ontario is far removed from becoming active in the drainage degradation of the quadrangle. Fall Creek, a tributary of the Cayuga valley over the eastern wall of which it now drops[1] at Ithaca, controls a large portion of the Moravia quadrangle. But the base-level represented by the water in Cayuga valley initiates a new drainage cycle for such parts of the quadrangle as are drained by Fall Creek. A recent cycle is also in operation for the valley tributary to the Owasco Inlet at Moravia. In all other respects this quadrangle occupies a prematurely advanced stage in its drainage cycle. The former major drainage line, that is, the valley now controlled by the Owasco Inlet, in its southern part has been so aggraded by glacial deposits that many of the streams which preceding the ice invasion were doing erosional work have in the main ceased to be agents of disintegration. This glacial interference with the erosion cycle is the same in kind as has become operative in all of these Finger Lake valleys. It becomes apparent, therefore, that one of the results of glaciation is the hastening of the position which drainage in its normal development would have brought about. On the other hand, certain upland valleys contiguous to these major drainage lines have been started on an entirely new cycle through the erosive work of ice in the longitudinal valleys to which the upland valleys were pre-glacially graded.

Distribution of the Drift.

GENERAL DISCUSSION.

In accounting for the veneer or for the deeper accumulations of drift found in glaciated countries, one considers both the local topography and the topographical aspect of probably all the area

[1] R. S. Tarr: *Am. Geologist*, vol. xxxiii (1904), pp. 271–91.

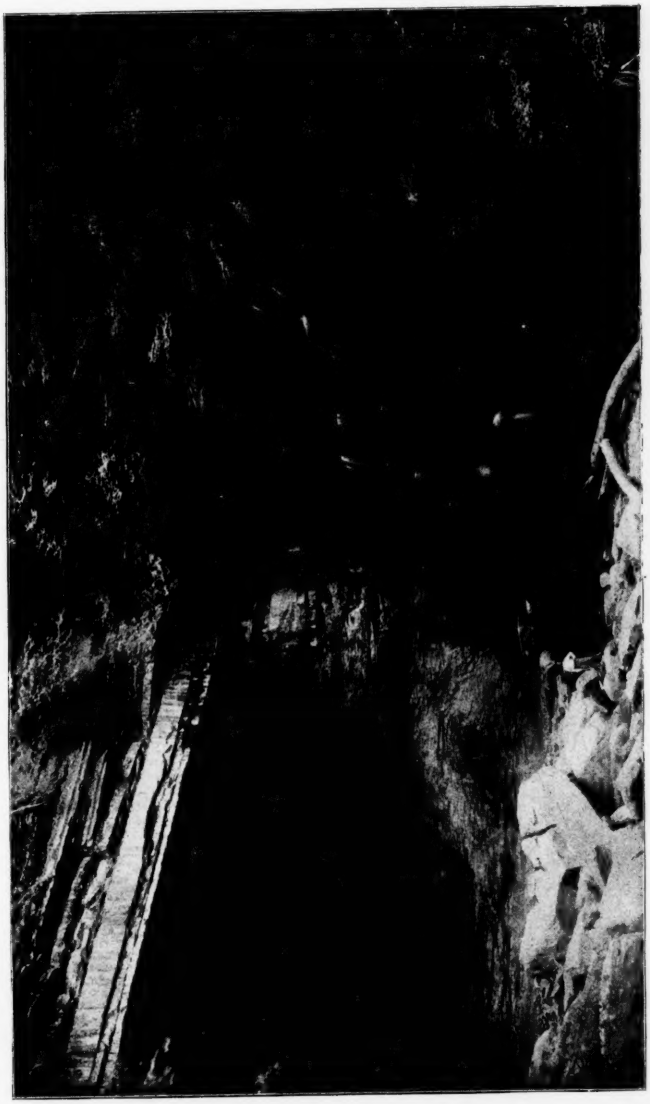


Fig. 6. A water fall due to the Tully limestone south of Moravia in Dry Run. Contact of Hamilton and Tully.

which intervenes along all the lines of ice movements between the region under discussion and the dispersion centers of the ice. The load which an ice sheet acquires doubtless depends in the first place upon the irregularity of the surface over which the ice is moving, and in the second place upon the attitude of that surface in reference to the dispersion area: that is, ice moving down a slope does not perform the abrasive work conducive to the acquirement of a great amount of débris, whereas ice moving against a slope is apt to take on much more rubbish. The lithological aspect likewise of the country being traversed is a factor of considerable importance. This factor enters into the question in two ways: (1) Stratigraphical terranes that are easily denuded either by erosion or by abrasion suffer more from an ice cap than do terranes that because of structure are less easily influenced by these agents. (2) On the other hand, the attitude of the rock formations regardless of the general slope of the country is a control in the acquirement of a load by glacial ice. In much the same manner, but to a less degree, the abrasive work of ice is accentuated when the movement is against the dip of the rock. It has been noted that on coasts where the rocks dip seaward, wave work is less effective. The analogy between the erosion of waves and ice may not be close; nevertheless there is a similarity in the mechanical principles involved.

It is apparent, therefore, that a cross-section of the ice sheet transverse to the axis of movement would reveal an irregular distribution of débris. This irregularity is due largely to the factors already discussed, that is, the topography, and the attitude and structure of the rocks over which the ice has moved. If the local topography were not a factor in the final disposition of drift by an ice-sheet, then any given moraine of an area would be the counterpart of the termini of the lines of rubbish carried by the ice at the time of that halt.

This consideration as yet has neglected the fact that ordinary ground moraine is the sum total of débris in the ice that finally covered the area of this moraine. The ideal example of such drift-accumulation is seen only when some portion of an ice-sheet becomes stagnant and decays. Then the load of drift in this stagnant ice will have, after melting, about the same areal distribution that it had when enclosed in the ice. So it follows that a considerable area of detached ice might be marked by an accu-

mulation of deposits corresponding to the points where the drift was localized in the ice. Only in limited areas, perhaps, is any ground moraine due to this combination of conditions.

When the ice-melting and the ice-supply are about equal the resulting accumulation of débris is simply the piling up at the ends of the lines of ice movement of such quantities of drift as the ice holds along these lines. The most typical illustration of débris thus assembled exists in the areas of thickened drift called terminal moraines, and along valley lobes and tongues which deposit drift known as lateral moraine and loops. Such bands represent the débris gathered by the ice along its paths of motion.

Furthermore, the upturning of layers in the ice results in shifting laterally considerable débris that otherwise might reach a distal position in accordance with the conditions mentioned above. This phenomenon has been observed in Greenland in both the ice-cap and the dependencies.[2]

The other great factor in the distribution of drift is found in the relief of the region under consideration. This control works itself out in two ways; first, the local topography to a large extent establishes the course of ice-front drainage; second, this local topography gives the ice-front its particular form. I will discuss these points in reverse order.

The influence which topography has on the outline of the ice-front is a question that can be unraveled largely through mapping the drift. Certain theoretical considerations, however, are of aid, since a semi-plastic body naturally assumes forms consequent upon the outlines of the area over which it rests. The ice will feed out farther along the more deeply incised valleys, and will be hindered in its progress by the highest divides. It follows, then, that if a given region contains valleys longitudinal to the direction of the ice-feeding, these valleys will each be occupied by a tongue or lobe of ice. When the ice with this irregular front maintains a fixed position, the feeding and the melting being about equal, drift accumulates in lines along its borders.

If, however, the area has slight relief, then the form of ice-front will reflect more nearly the lines of impulse of the ice-sheet. This principle would give us in a fairly level country a uniform ice-

[2] R. D. Salisbury: *Jour. of Geol.*, vol. iv (1896), p. 791. Chamberlin and Salisbury: *Geology*, vol. i (1904), pp. 282–83.

front, and the drift which accumulates from such an ice-front would take somewhat the outline of an arc whose ultimate radii converge towards the dispersion centers of the ice. But it is rare that the dispersion centers so completely control the outlines of the ice in distant parts. With an expanse of intervening lowlands and highlands, the original impulse suffers so many deflections that the resultant lines of movement in distal areas betray this impulse in only a slight degree; consequently when we are dealing with an area quite removed from the ice-dispersion centers, as the St. Lawrence-Susquehanna divide region is, this latter factor may be largely neglected.

Nevertheless the topographic influence exercised by the Ontario basin, inducing in the ice, once at least in its progress and once again in its retreat, a marked lobation, is a feature so pertinent to the whole matter of drift distribution to the south as to warrant some consideration. The general features of the Ontario lobe have been understood by glacialists, with a fairly apt appreciation, since Chamberlin's[3] work on the moraines of the "Second Glacial Epoch." The contributions to a study of the control exercised by this lobe, made by Gilbert, Spencer, Taylor, Tarr, Fairchild, and others, constitute an inclusive study that gives certainty to a paper which concerns the smaller dependencies or valley lobes of this larger body of ice. The Ontario lowland formed as it were a great reservoir which insured a degree of constancy in the position of the ice as it reached southward through the Finger lake valleys.

From a study of existing ice areas, it is probable that cyclic and climatic factors manifested themselves in the pulsations of activity shown by the continental ice-sheet. The variations of the smaller glaciers of Alaska, of the Alps, and of the dependencies to the Greenland ice-cap, all point to irregularity in the rate of feeding of the ice. When a given region lies leeward of such a basin as the Ontario area it is evident that these cyclic or seasonal variations will be less manifest, the intervening low section acting as a reservoir. In a similar manner rivers are subject to control in their flood seasons. Because of this fact there probably were fewer important local readvances of the ice in the Finger lake region than in such topography as is found in the upper Mississippi valley.

[3] U. S. Geol. Surv., Third Ann. Rep. (1883), *Preliminary Paper on the Terminal Moraine of the Second Glacial Epoch.*

DRIFT IN VALLEYS.

The stationary position of ice tongues or lobes in valleys is generally marked by a loop of drift. The development which such loops across valleys may attain is dependent upon the following factors:

(1) *The Load Carried by the Ice.* It is needless to say that ice which contains no débris fails to register the position of its front. It is equally apparent, however, that in a topography of even slight relief the ice while passing over it accumulates some material so that where dissection has produced valleys maintaining tongues a halt of even short duration will be marked by drift; and that greater surface inequality, and a slope of the valley floor toward the ice, thus offering obstruction to its progress, furnish the conditions requisite for the deposition of thicker loops of drift.

(2) *The Grade of the Valley.* The velocity of ice-front streams, and consequently the load that they are capable of transporting, depends on the slope of the valley floor. When these streams have slight velocity the débris gathering from the ice is more apt to be transported and deposited as a valley train. A sluggish stream, or a slackwater condition in front of the ice, offers a favorable condition to the building up of a valley train. Probably the topographic association, on the supposition that the ice contains a good load of rubbish, most conducive to the development of a valley-loop, requires also a gentle slope, and a corresponding low velocity in the streams leading away from the ice. A valley tongue which extends into a static body of water, as was very often the case in the Finger lake region, should be marked by conspicuous frontal accumulations of drift. In this case wave work, and the tendency of the finer débris to be carried off in suspension, are factors that in no wise antagonize the formation of heavy loops.

(3) *The Time Factor.* The degree of development of this form of drift is directly controlled by the length of time that the ice maintains a permanent position: in other words, the period during which the melting and feeding factors are about equal. Even this condition requires a little closer analysis since it is evident that a low rate of ice-feeding accompanied by equally slight melting, thus insuring a permanent position, destroys a minimum of ice; a thickened loop of drift in most cases represents the decay of much ice. Therefore, when the ratio of feeding and melting,

both factors being active, approximates unity, we have the combination most favorable to producing valley loops.

(4) *Texture of the Drift.* The nature of the débris being accumulated likewise exercises some control over the development attained by the loop. This control is shown more perhaps in the form of the loop. The coarser the material being assembled, the higher will be the loop. When the drift contains a large percentage of clay, which when moist has a tendency to slump, the loop will be low but broad; when the drainage of the valley is ponded, this slumping will be more pronounced; but even in the absence of static waters, which induce a genetic broadening of loops, postglacial weathering tends to flatten them if much clay is present. Likewise the condition of its gravel content, whether fine or coarse, if sufficiently abundant, manifests itself in the slope of the loop.

THE OUTLINE OF VALLEY LOOPS.

Since this form of drift marks the front of the ice, it is evident that there are controls to which the shape of the ice-tongue itself is subject, and which in ultimate analysis determine the outline of the loop:

(1) Obviously the *width of the valley*, a feature contingent upon stage of development and upon the stratigraphy, will give two types of loops. In a valley of gently sloping side walls, the form usually found in areas of fairly homogeneous rock structure, the loop formed is more symmetrical. It consists of two divisions, the flood plain segment, and the lateral segments. When the valley is wide, the flood plain segment is relatively narrower, a condition due to the tendency of the ice-tongue to protrude along the axis of the valley. The lateral segments consist each of two arcs. The portion higher up the valley wall has a longer radius, i. e., slighter curvature, than the portion near the flood plain segment. It is apparent that the arc of the loop flattens as we pass along it in either direction from the axis of the valley.

But valleys having steep side walls, a condition due either to lack of maturity or to less resistant rock in which the valley is floored, underlying a more resistant formation, tend to shorten the arc of the flood plain segment of the loop; that is, the portion of the loop in the bottom of the valley is narrower than in the former case.

(2) It appears furthermore that the course taken by a loop in crossing a valley depends also on the *depth of the valley.* In deep valleys which have gently sloping side walls, the tongue of ice reaches farthest ahead of the main ice-front. Consequently the loop formed is more symmetrical, the lateral segments being many times longer than the flood plain segment. The lateral segments likewise drop so gently into the lowest part of the valley that they present a diagrammatic[4] appearance. It is evident, therefore, that this control is better illustrated in mature valleys, such as those now occupied by the Finger lakes.

(3) The form of loop may also reflect a *lack of symmetry* in *the cross-section of the valley.* It not infrequently happens that a spur of one side-wall is opposed to a gentle slope on the opposite side. A cross-section of the valley at this point gives unsymmetrical slopes, and exerts a control on a loop developed there. Such a control gives the drift-loop on one of its sides a very straight or ridge-like appearance, the direction of the ridge marking the axis of feeding of the ice-tongue.

(4) *The relation sustained by the valley axis to the direction of ice-movement* will also have an influence on the general outline of valley loops. Usually the topography exerts a strong control over the direction of ice motion along its more attenuated front, but this control is effective up to a certain relation of these axes, beyond which the direction of motion of the ice sheet decides the course taken by the loop in crossing a valley. Thus it happens that a loop, near the point of junction of two or more fairly mature valleys, may sustain a position anywhere between coincidence with the axis of the valley and at right angles to this axis.

(5) *The influence of marginal streams,* as described by Tarr,[5] is frequently shown in the lateral segments of loops, producing sometimes a lopsided development. Slight oscillations of the ice-front cause a shifting of streams lateral to the valley lobes; both the erosion work of these streams and their unequal deposition of load tend to the asymmetrical development of loops.

[4] R. S. Tarr, *Bull. Geol. Soc. Am.*, vol. 16 (1905), p. 218.
[5] *Bull. Geol. Soc. Am.*, vol. 16 (1905), p. 222.

VALLEY LOOPS OF THE MORAVIA QUADRANGLE.

The generalizations in the above section have been deduced from a study of the loops detailed below:

(1) *In the Freeville-Moravia Valley.* It is recalled (p. 340) that this valley is probably composite in origin. At present it conveys through-drainage to the north from about the area of Freeville; in the genesis of this valley a divide doubtless formerly existed a mile or so north of Groton, from which water flowed in either direction. This constriction in the rock-confines of the valley had some slight effect at least upon the outline of the valley tongue which occupied the Freeville-Moravia area during the retreatal halts of the ice. The general direction of the valley is quite accordant with the general direction of ice motion. This fact accounts for the many typically developed loops found in the valley.

"A." Extending southeastward from the vicinity of the George Junior Republic is a conspicuous ridge of drift, shown in fig. 7. The massiveness of this ridge taken into consideration with the great accumulation of drift contiguous to it, but slightly to the north, with also the thickened drift southward from Freeville against the south wall of the old Fall Creek valley (See Dryden Quadrangle) indicates a rather long halt of the ice. By consulting the combined topographic map it is observed that a mature valley extends northward towards the Freeville area from the direction of Dryden lake. This mature valley during several stages of the ice retreat carried valley dependencies whose positions may now be read from the loops, but when the ice had retreated northward to the position occupied when the loop under discussion was being developed, the front of the ice did not extend to the southeast into this old valley, but maintained a general north-south line across the mouth of the valley. In other words, the general position of the ice in the Moravia area at this time reflected the larger control being exerted by the lowland of the Cayuga valley. In this Cayuga valley the ice then reached much farther south than Freeville, so that the halt connected genetically with the loop under discussion was contemporaneous with a halt several miles south of Ithaca.

An examination of this loop shows that it contains a large percentage of clay, with some gravel. That this loop had a genetic

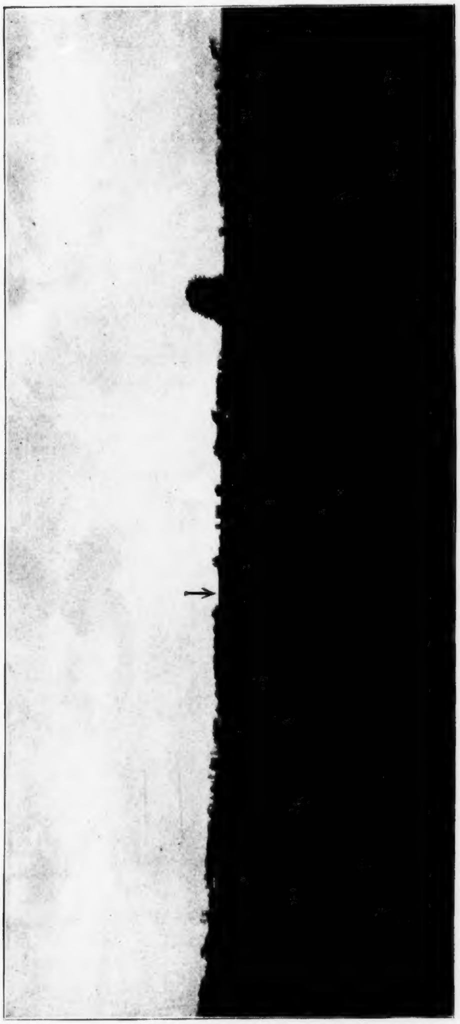


Fig. 7. Loop "A" from the east. Camera stands near northern margin of the Dryden sheet, and points a little south of west. The arrow indicates cut made by railroad in this loop.

Fig. 8. West segment of loop "E" viewed from south. Loop blends into drift covering valley wall near left margin of view. Just to right of smokestack the loop has been cut by a stream; the west end of the other segment shows on extreme right. Sag-and-swell valley drift appears in foreground.

association with the conspicuous kame-area at Freeville and northward is a question discussed in another place.

"B." Just north of Freeville where the recently constructed highway reaches westward across the valley one notes an inconspicuous accumulation of drift, suggesting a temporary position of the ice. This drift does not average over eight feet above the general outwash plain, but the alignment of scattered knolls indicates that the ice halted here briefly at least. The outwash gravels of a later ice-halt, and wave work of an ice-front lake which later covered the area have rendered less conspicuous this loop which had slight initial development.

"C." At Peruville, an alluvial fan on the west side of the valley reaches out almost to the drift which flanks the opposite side of the valley. It is noted, too, that the lingering of the ice at this point probably commenced slightly south of the present southward slope of this alluvial fan, but the melting and feeding factors lacked enough of being balanced so that a rather wide, low band of drift was developed across the valley. The abundance of washed deposits into which this loop blends on the east side, where the fan has not partially buried it, is a condition that will be discussed elsewhere in connection with the fact that in this part of our quadrangle the kame type of drift apparently predominates.

"D." About half way between Peruville and Groton, the drift which all the distance covers the walls of the valley, particularly the east wall to a considerable depth, narrows down into a ridge across the valley. We have to bear in mind constantly that through a large part of this Freeville-Moravia valley, moraine terraces and other forms of valley drift are so thoroughly developed that there is a tendency to mask the accumulation which would mark the position maintained for any essential length of time by the valley tongue. This condition perhaps accounts for the fact that some of these loops are so inconspicuously developed in the bottom of the valley that their diagnosis as moraines would hardly be permissible without the association of analogous drift higher up on the valley walls.

"E". Extending across the valley at Groton is another loop which has been cut through by a drainage channel probably from its early history. The ice-front drainage maintained for some time after the ice had retreated far northward in the valley, an outlet to the south. It is thus that the ridge of drift at Groton is

not complete. As shown by figures 8 and 9 it is evident that the west segment of this loop is more conspicuously developed. In connection with this fact it may be observed that the east wall of this valley carries everywhere a great complex of drift, so that the normal condition of the east segments of nearly all the loops is a lack of distinctness brought about through the massing of drift by marginal drainage. It may be stated further that the material constituting these loops is uniformly more gravelly in the eastern than in the western segment. This fact is especially well illustrated in the Groton loop, as here the west segment consists prevailingly of till in which clay predominates, while the east segment discloses a great amount of gravel as exposed where cut into by the streets crossing it and passing over it up the slope, as well as in the pits that have been opened for road-making material, and also in the fact that the village cemetery is located on its top.

"F." Proceeding northward the present valley pinches down at the boundary line between Tompkins and Cayuga counties. Here the loop (fig. 10) is only less distinct than at Groton, and repeats the same arrangement as to the predominating constituents in the two segments. The prevalence of clay in the western part of this loop is the normal condition of the drift, not only at this point in the valley, but for about two miles to the north and rising up the slope to the west. On the other hand, the eastern segment of the loop, the eastern wall of the valley, and the adjacent uplands bear drift in which washed material predominates.

"G." About three-fourths of a mile southeast of Locke there extends out into the valley bottom from the east wall a conspicuous ridge of till whose axis of direction is not in harmony with the position of a valley loop. That the material is predominantly clay, containing many large bowlders, is evidence that the ice here maintained for some time a fairly constant position, but the direction of the ridge is somewhat puzzling. It may be suggested that this particular ridge is the resultant of erosion. If so the reëntrant angles, particularly on the north side, have lost all evidence of stream work such as would suggest this genesis for the axis of the ridge. Neither is there a catchment basin, nor at present any indication of springs that might furnish the water for the degradational work. In this connection it may be noted that just west of the present inlet stream and railway there appear beneath the

Fig. 9. Looking north of east across the Owasco Inlet valley about one-half mile south of Groton. The opposite valley wall is heavily covered with drift, locally quite kame-like. The entire arc of loop "E" (fig. 8) shows, commencing at the extreme left and blending into opposite wall northeast of the village. The arrow locates delta "B."

Fig. 10. Looking southward through loop "F;" the crest of the west segment of loop "E" shows in this gap. A ridge shows on right; note how all of this ridge, which is composed almost entirely of clay, save the northern end, has slumped forming a corrugated surface.

delta several exposures of till which may correlate with this ridge; the location of the deposit of till now buried by the washed material of the delta conforms to the general trend of the ridge on the east side of the valley.

"H." North of Locke, about one-half mile, reaching out from the east side of the valley, is an accumulation of drift that suggests a halt in the ice. The analogous segment on the west wall is not well developed, if it ever existed, but there is noted along this west wall a large amount of till that probably represents the slow retreat of the ice, not a permanent halt. The suggestion of a loop on the east side may on the other hand represent a concen

Fig. 11. Looking southward on the west segment of loop "I."

tration of drift, as the sections in it show an abundance of washed material from the region north and east, that is, the accumulations of lateral-tongue drainage. This area of drift was originally irregular, and stream erosion has since greatly increased the irregularity.

"I." About one mile north of this last loop a more marked frontal lobe accumulation of drift crosses the valley. On either side this loop attains a fairly uniform development, and is especially marked by the abundance of washed drift in the form of kames. This is particularly true on the western segment of the loop as appears in fig. 11. The outwash in the valley southward to the loop discussed under "H" is well developed.

Northward from this halt the ice, so far as the drift in the valley affords evidence, suffered a more rapid retreat. At any rate, no well-developed loops cross the valley; nevertheless both walls suggest a less rapid retreat of the ice in that they are fairly well mantled with irregularly distributed drift. Having in mind that the retreating ice in the region of the lakes constantly held in front of it, through several degrees of latitude, static bodies of water into which streams from the well dissected lands were pouring their load of gravel, sand and silt, and the further fact that the later ice-front lakes were of longer duration than the earlier ones, and consequently spread over their bottoms a greater amount of lake deposits, it is to be expected that mild loops, formed with the slight halts of the ice, have been largely obliterated. A long duration of such a series of factors would tend to efface the evidence of loops that formerly existed in this segment of the Freeville-Moravia valley. Furthermore, it is probable that the frontal parts of these loops were largely disseminated through the static water into which the loops were being deposited.

(2) *In Fall Creek Valley.* It is recalled from the discussion under drainage that the most mature topography of the Moravia quadrangle is found in, and adjacent to, the Fall Creek valley. We recall also the fact that at McLean this Fall Creek valley, as marked on the Moravia sheet, joins a master valley extending southwestward towards Ithaca. The maturity of development found in both the master stream and the tributary have tended to produce, during the retreating stages of the glacier, a more evenly outlined form of ice-lobe; the gently rising side walls and the preglacial width of the valley bottom give us here quite a different type of loop than that described in the Freeville-Moravia valley.

"J." In passing north and east from Freeville along the Lehigh Valley Railroad one notes in the vicinity of Red Mill the converging, toward the valley-bottom, of the massive kame accumulations, particularly those on the eastern side of the valley. A short distance north from this place, at Malloryville, the valley becomes quite completely clogged with glacial débris. The typical developed esker (fig. 18) described elsewhere in this paper is found at this place. Kettle holes and other phenomena especially characteristic of washed drift are numerous. The present stream has sluggishly picked its way through the massive accumu-

lations of drift. This marked development continues to barricade the valley almost to McLean (fig. 21) a distance of fully three-fourths of a mile. At McLean the bottom of the valley again presents the wide flood plain appearance already alluded to north-east of Freeville. This accumulation of drift represents rather more perhaps than the mere halt of a valley tongue or lobe of ice. Its general appearance, however, in crossing the valley tends to bring the drift under the category of valley loops. A fuller discussion, however, of this particular area is g ven under Kames, since the predominating type of drift in this area is the kame.

"K." Proceeding northward from McLean one notes the rather constant mass of drift that the valley carries, more especially along its western wall. The three highways that terminate in the east-west road passing through Nubia cross the drift just alluded to. The easternmost of these highways cuts through less glacial material than the other two; in fact, during the last half mile before reaching Nubia, the rock slope is slightly mantled.

At the village of Nubia, however, the position maintained by the ice-front is more strikingly shown; a wall or ridge of drift presents a convex outline as we proceed northward and for a quarter of a mile it is evident that the ice receded very slowly, as one is able to easily decipher briefer but very clear halts. Here, too, the bulk of the drift flanks the western wall of the valley.

"L." For about two miles, as we proceed northward, the drift on valley bottom and the side walls is monotonously uniform approaching Rogers Corners, east of which place there enters the major valley from the east a fairly mature tributary. The position which the ice maintained, with two tongues abutting the rock salient that extends northward between these valleys, is most plainly seen in the location of the drift ridges across the two valleys. Fig. 12 shows the appearance of a valley loop in the tributary valley; the ice-front drainage here was not as free as in the major stream. Furthermore, the topography to the east tended to concentrate into the tributary valley a large amount of drift brought by streams aligning the flank of the ice tongue; hence, the more conspicuous development of this latter loop.

"M." For the next mile northward the flood plain is not interrupted by ridges of drift, but just south of Lake Como, where the highway forks across the valley, a stationary position of the ice is read in the band of drift that intercepts the outwash.

Fig. 12. Looking southeastward from top of drift designated loop "L." This lies east of Rogers Corners in a valley tributary to Fall Creek valley.

A relationship of major and minor valleys, similar to that just described, exists also at this point. The direction, however, of the tributary valley is more normal to the major stream, and therefore has not offered as favorable a topographical position for the development of a loop.

Lake Como, an unusually large kettle lake, is bordered on the north and east (figs. 14, 15) by leveled drift hills in which gravel largely predominates. The kame-like aspect of the drift to the north and east of the lake is suggestive of the particular outline that the ice-front, as it lingered in this region, presented.

"N." For something more than two miles north of the village of Como the drift of Fall Creek valley does not indicate any long stationary halts of the ice, but near the present divide of the Fall Creek-Bear swamp drainage areas we have a well developed mass of drift which analyses itself into two or possibly three positions of the ice. The drift, however, is so irregularly dissected in part probably because of the drainage which came through this section as the ice was in the neighborhood north, and in part too because of the lateral valley slopes, that one does not feel safe in a final statement as to the several distinct positions which the front of the valley tongue may have maintained. The southern line of the next quadrangle north cuts a valley loop, the major portion of which lies within the Skaneateles quadrangle.

(3) *Other Loops Principally in Tributary Valleys.* "O." The Skaneateles Inlet valley presents a mass of drift that cannot be differentiated into loops, if they exist, without a more complete study of the region to the east which lies without the quadrangle. Fig. 13 gives a general idea of the irregular surface of the drift which buries this valley.

"P." At Dresserville there is a strong suggestion of an ice-halt. The valley here is evidently deeply buried with drift, as is shown by well sections, some distance away from its axis. But in the main, this valley, especially north from Dresserville towards Morse Mill, presents such a heterogeneous surface that one does not feel safe in interpreting the drift from a standpoint of valley loops. There are, however, some very marked suggestions, particularly on the eastern wall, of aligned deposits of drift that intimate the loop type.

"Q." At Wilson's Corners about a mile north of Montville the valley is completely barricaded by a very distinct loop. The

position maintained here by the valley tongue reflects topographic relations that exist on the north in the Skaneateles quadrangle. The outwash material synchronous with this loop has been masked by the delta and the other deposits of static water-body streams.

"R." Just east of North Summer Hill is the well developed loop, alluded to in the discussion of drainage (p.343.) The ice fed into this rather moderately developed valley from the northwest. The loop does not suggest a long halt of the ice.

OTHER FORMS ASSUMED BY DRIFT IN VALLEYS.

(1) The few suggestions already made to the problems one often meets in deciphering loops intimated the type of drift, if the distinction is sufficient to warrant such a classification, that I attempt to give in the present category. One who has been around these Finger lake valleys is familiar with the localities where drift seems to clog the valley in a manner both without system and apparently without any particular or definable position of the ice genetically contiguous to the drift. For the purposes of classification we might designate such areas of glacial débris as *massed*[6] *valley moraine*. For the formation of such drift accumulations three conditions, as it appeals to me, are requisite: (1) A period of time during which the ratio of the feeding and melting factors is a little less than unity. This condition then assures a fairly stationary position of the ice, and with ice that carries a heavy load much débris must accumulate. (2) Another requisite condition is such a topographic relation of valley floors and side walls as tend to concentrate toward the axis of the valley the load carried by the streams flowing along and out from the margin of the ice. It is conceded that an amount of water abnormal to the present drainage in similar valleys must have trended towards the ice tongues throughout the retreatal stages. This water especially during the seasons of flood would cut both the drift already deposited, eroding it in a brief space of time into roughened forms, and tend to remove more speedily the débris contemporaneously collecting at the foot of the ice walls. The pertinency

[6] Tarr discusses similar deposits under the heading "Moraine Complex in the Upper Cayuga and Seneca Valleys," *Bull. Geol. Soc. Am.* vol. 16 (1905), pp. 225–27. Professor Tarr also uses the term "morainic complex" for moraine in the uplands which does not correlate with traceable moraine bands (*Ibid.*, p. 223).

of the latter condition is dependent directly upon the slope of the valley in which the tongue lies; only when the valley slopes away from the tongue would this vigorous drainage at the axis of the valley obtain. (3) Reports of existing glaciers of a type more analogous to the lobes that characterized the front of the ice-cap often mention the tendency of crevasses to reach inward from the lateral slopes of the valley tongue. When the ice is relatively stagnant and the conditions of drainage exist as described under No. 2, these crevasses would not only be filled with rubbish, but[7] with the normal melting would be enlarged till the accumulation of débris prevented further melting. Such conditions would account for some of the ridges of drift that are so reticulated in arrangement as to make their interpretation as valley loops absurd.

Another feature of the above discussion follows as a corollary when there is a large amount of clay present in the drift. The scars of recent land-slips in the very areas under discussion show how at the present time the irregularity of the drift is being emphasized. Glacial till in which clay predominates weathers more perhaps through solifluction than through erosion, and while solifluction need not necessarily render a topography more irregular, it is evident that wet clay when moving in mass produces scar-slopes that are much sharper than the initial surface.

The best illustrations on the quadrangle of drift of this heterogeneous type exist in the Skaneateles Inlet valley (fig. 13) and in the valley southeast of Morse Mill. Milder surfaces, though similar perhaps in genesis, are noted in the Fall Creek valley north of McLean against the west slope, and northeast of Groton in the Freeville-Moravia valley.

(2) *Terraces.* Along the walls of valleys once occupied by tongues of ice are found terraces formed of materials dropped from the ice, and of débris deposited by marginal streams. During the continuance of the glacier, these deposits tended to level up the depressions between the ice and the valley wall. Wherever this marginal drainage was locally slack, or was temporarily ponded, much clay entered into the débris being collected. At the melting back of the glacier, the ice-contact face of these deposits assumed a lower angle, as shown by Watson.[8] The

[7] Tarr: *Zeitschrift für Gletscherkunde,* band iii (1908), p. 87.
[8] *New York State Museum Report,* vol. 51 (1897), p. 178, figs. 12, 13.

present slope of the marginal terraces and their evenness of front depend upon the material composing them. When clay is present in quantity the terrace is apt to be represented by a series of alluvial fan-like ridges, but disproportionately long in direction normal to the proper front of the terrace, which from a distance appear as corrugations on the valley wall. When, however, gravel is conspicuously present the terrace longer maintains its original form. The most typical illustration on the Moravia quadrangle of the corrugated slopes which may characterize terraces is seen

Fig. 13. Kame phase of the drift in Skaneateles Inlet valley.

towards the foot of the valley wall southwest of Moravia. At first sight it might appear that these short ridges and intervening troughs are but the normal result of erosion. A closer study on the ground shows that the clay, so abundant, has assumed this form through a long series of slippings, thus illustrating the type of weathering known as solifluction.[9]

The normal moraine terrace, as studied in valleys, has been

[9] J. G. Anderson: *Journal of Geology*, vol. xiv (1906), pp. 91–112.

so frequently and accurately described[10] that no further reference is needed here.

(3) *Ridges.* There appears in all the valleys studied a persistent form of drift which it seems most natural to classify under this heading, although the name is not at all suggestive of origin or development. They consist more frequently of till; but gravel sections occur in many of them. They vary much in length, the longest one noted measuring about one-half mile, while the general length is less than twenty rods.

In general direction these ridges are either transverse or longitudinal. As to their method of formation they may be constructional or destructional. As a general condition, however, this form of valley drift is found near the foot of the valley walls, seldom out very far in the flood plain.

One form of the constructional type is shown in figure 10. This was made of débris accumulating along the margin of the valley tongue, and consists largely of till. The northern end of this ridge resembles a kame; southward the ridge has lost its original height through slumping to both sides. A longitudinal section shows a decline from 60 feet at the north to zero at the south; the sides at the higher part slope 24° to 26°. Clay predominates in the southern part, whereas gravel increases towards the northern end of the ridge.

Another constructional form of ridge may be developed in the distal area of a valley lobe which, following a period of less activity, has developed openings or crevasses in consequence of an advance;[11] the ridges represent the concentration of débris by streams. Glacial drainage is not connected with this particular type of drift save when very near the edge of the ice. It frequently happened that tributary valleys were occupied by the lateral tongues of ice which in position were transverse to the drainage flowing from the north along the margin of the ice lobe. In this condition probably the stream for some distance had its bed over the ice which thus reached out into the tributary valley. That a super-glacial course of streams always hypothecates such an arrangement of valley lobe and lateral tongue is not implied.

[10] Chamberlin: *Third Ann. Report*, U. S. Geol. Surv. (1883), p. 304. Gilbert: *Monograph I*, U. S. Geol. Surv. (1890), pp. 81–83. Tarr: *Phys. Geog. of New York State* (1902), p. 85.

[11] Tarr: *Zeitschrift für Gletscherkunde*, band iii (1908), p. 99.

The only condition insisted upon in this form of the constructional type of ridge is that the coincidence of such a stream course and one or more crevasses would give the requisite relation of ice and a loaded stream to produce the accumulation of débris noted in these ridges.

The destructional ridge results from the erosional work of ice-front streams whose courses have been shifted either by a slight advance of the ice or by a barrier derived from a localized greater load of débris in the ice. The suggestion as to a localized condition of débris is found in the reports[12] of Chamberlin & Salisbury's studies in Greenland.

(4) *Isolated Hillocks.* A featureless outwash plain is sometimes most surprisingly interrupted by a lone hill of drift often so symmetrical in development as to suggest artificial origin. I have also seen a few such hills on the upland near the east side of the valley between Locke and Groton. They consist of both till and washed deposits, the latter being more common. As to origin, it seems reasonable that these lone hills of drift may mark the brief continuance of factors which would produce, if given more time, some of the ridges described in the preceding section; subdued moulin work might make such hills. It is not forgotten that a considerable degree of symmetry might in time be developed by normal subaërial erosion on an original mass of drift less regular in outline. The fact, however, that no constant condition as to water-laid or ice-laid drift is prevalent in these hills precludes our interpreting them as less well developed kames.

(5) *Kame Areas.* Hillocky areas of prevailingly stratified drift are formed in valleys either at the margin of the ice or back aways from the front as the ice becomes rather stagnant. Such areas are noted in the triangular plains that mark the union of mature valleys. They are likewise noted along the valley walls in the intervals between loops of drift. This type of drift in which washed material predominates has also been observed in the higher area between valleys. The promiscuous location of these kame areas tends to eliminate a topographic control as the sole factor in their genesis, though it is evident that more of such drift is found in some topographic relations than in others.

The most extensive kame-area of this sheet is found east and

[12] *Geology*, vol. i, (1904), pp. 296–97.

north from Freeville. The kames of this region have already been given a place in the literature of glacial geology.[13] While the kames here are conspicuously developed, nevertheless they are no more typical than are those formed northward in Fall Creek valley about McLean. Both well records, and sections exposed in excavations, reveal the constant presence of water in the genesis of this drift. Numerous kettle holes are suggestive of a stagnant condition of detached portions, at least, of ice. The distorted layers noted in some sections suggest either slight readvances of the ice, or slumping, following the accumulation of this washed drift.

Bearing in mind the control exercised by the Cayuga valley on the lobation of the ice-front, we are able to understand how this mature Fall Creek valley is so largely filled with drift in the area between McLean and Freeville. For the sake of emphasis in this relationship of controlling-topography and position of the ice-front in this area it is assumed that the general direction of the Fall Creek valley from McLean towards Ithaca may have been coincident, for a time at least, with the front of the ice along the eastern part of the Cayuga lobe. In this relationship we are ignoring minor tongues which were encouraged by the lesser details of topography. The existence of these minor tongues has tended, it is evident, to facilitate the accumulation of this washed drift in the region under discussion. Extending southeastward from Freeville is the Dryden valley which was occupied by a dependency of ice that gradually shortened in length as the general front of ice moved northward. That Dryden valley continued to be a factor in the outline of the ice-front even after it had ceased to be occupied by a tongue of ice is evident from the discussion already given of the valley loop which reaches southward from the vicinity of George Junior Republic (p. 354). This loop marks a static condition of ice showing that for a considerable time the general front of the glacier, approaching Ithaca from the vicinity of McLean, was convex toward the Dryden valley but did not extend into it.

Because of such a relationship then, a condition of slackened-ice-front drainage obtained during the retreat of the ice in the McLean-Freeville region. Observing the relief of the region

[13] R. S. Tarr: *Phys. Geog. of New York State* (1902), fig. 68.

to the north and east, we note a topographic environment that directed into this area of kames a large amount of drainage both along the general front of the ice and from the higher ridges towards Virgil in the Cortland quadrangle. A more or less stationary ice mass bearing a considerable load offers an added explanation for the peculiar localization of stratified drift and of outwash deposits found in the vicinity of Freeville. While this discussion has emphasized a relationship that existed for some time as shown by the valley loops already described, I am not overlooking the fact that this somewhat stationary position of the ice probably was slowly reached and as slowly receded from; during this period of gradual change a great amount of gravel and other washed material was accumulating.

While in the main I have considered the kame areas in the Freeville-McLean region as quite identical in development, there are, nevertheless, some features that indicate partial independence of origin. By consulting the topographic map we note, a short distance east of Red Mill, a slight creek that follows the sags across the irregular drift reaching ultimately out onto the flood plain. The limited catchment basin which this stream has, when considered from the standpoint of the well developed crease it occupies, proves the former erosive work of an active stream. This fact leads me to conclude that the kame area south of McLean is in part of later chronology than the Freeville kame area. The creek occupies a valley which it never could have cut with any such amount of water as might flow under normal conditions from the basins which it drains. Its more mature course has an axis which leads it westward of the Freeville kame district. In other words, the portion of the Freeville kame area that reaches nearest Red Mill was in existence when ice-front drainage cut the channel now occupied by this slight creek, and accordingly it is concluded that the conditions for drift-accumulation were present in the vicinity of McLean long after the ice had entirely withdrawn from the immediate region of Freeville. The portion of the McLean kame area which probably is contemporaneous with the first formed part at least of the Freeville kame area lies near the eastern wall of the Fall Creek valley in the vicinity of, and immediately south and east of, Mud Pond.

The connection of the Malloryville esker with the washed drift north of this village is discussed in the chapter on Eskers. It may

be said here, however, that after very detailed work in the field there appears to be no genetic association between these kames and the esker. Hills of washed drift contemporaneous in origin with the Malloryville esker lie to the west; probably a much longer esker was developed than may now be deciphered, for the reason that the kame type of drift filling the portion of the valley into which the esker leads has apparently buried a part of the esker ridge.

The striking kame topography south and west of McLean is apparently more typical for this type of drift than similar accumulations noted elsewhere on the sheet. In the immediate vicinity an ice-front lake occupied for some time this part of the valley. A delta was built into this body of water at McLean; otherwise the broken kame topography is not interrupted till we reach the flood plain deposits some distance east.

In the wide valley extending northeastward towards Cortland there is near the edge of the sheet, but more typically developed just over the boundary in the Cortland quadrangle, another area of kames. Here too, as in the Freeville region, the maximum development is on the south or east wall of the valley.

Another conspicuous group of drift hills, prevailingly washed in texture, skirts the shores of Lake Como (fig. 14). The kames of this region are not distinctly different, save in their slighter development, than the sections already described; that many of these drift knolls have been altered is evident from the photograph shown in figure 15. Apparently a static body of water stood here in front of the ice; its greatest areal extent endured pending the cutting down of its outlet through the driftloop just south; lake Como is the remnant of this larger lake. The level of the former lake coincided approximately with the tops of many of the drift-hills; waves attacked the drift distributing the products; the process continued as the outlet was lowered; accordingly many of these knolls now present a very flat-topped appearance.

In this section, too, an esker of sharp development leads southwestward from a slight kame area near the road crossings designated Como.

The massed drift which now constitutes the divide between the headwaters of Fall Creek and Bear Swamp Creek is, in localities, very kamy; but the water-laid deposits are not sufficiently developed to designate the region as a typical kame area.

Along the east wall of the valley north of Groton the general drift in areas consists prevailingly of washed materials in rounded knolls, and sometimes more strongly developed. This is especially true in the vicinity of the loop near the boundary line of Tompkins and Cayuga counties. In this region, and for three-quarters of a mile east, the kame aspect of the drift predominates.

Again, on the east wall of the valley near Locke (fig. 4) the highway leading to Summer Hill passes through very strikingly developed hills of washed drift. The topography here indicates

Fig. 14. Looking westward over kame deposits north of Lake Como.

slackened drainage, as at least a temporary condition, of ice-front waters.

A mile or so west of Locke in the vicinity of Goose Tree the water-laid content of the drift is so conspicuous as to intimate conditions that produce the kame type of deposit. This may be said of much of the drift of this area, both south and west, and southwest to North Lansing.

About a mile east of West Groton the front of the ice, in this broad divide area, offered the right relationship for producing a predominance of water-laid drift. The moraine band here for

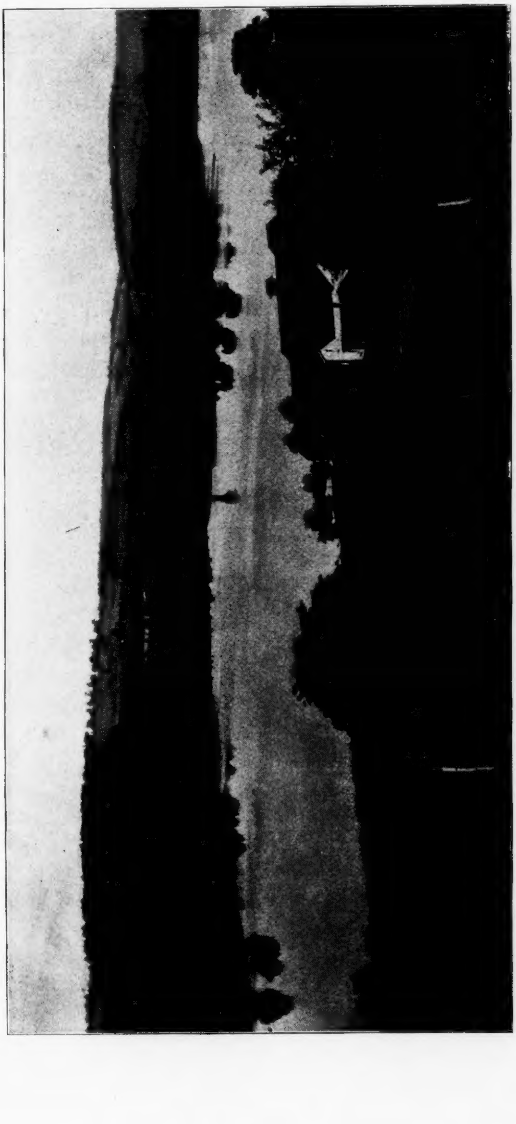


Fig. 15. Looking eastward over Lake Como. In line with the house in foreground is seen an area of even surfaced drift. To the left of the buildings across the lake is seen a portion of the kame area shown in fig. 14.

some three-quarters of a mile is very kamy both in surface appearance and in texture.

From Benson Corners the drift for one and one-half miles south and east is made up of a maze of water-laid hills, (fig. 16), most irregularly distributed. Locally this belt of moraine is over one-half mile wide. Also, the kame aspect is very marked along the ice-front southwestward toward Asbury.

In the vicinity of West Dryden the kame type likewise characterizes the drift. Indeed, the isolated areas in which water-laid moraine prevails are found irregularly scattered about the whole sheet.

In this rather detailed inventory but two more particular localities need be mentioned. Immediately westward from Fitts Corners the kame aspect of the drift is accentuated. This locality is on the divide between the Moravia-Freeville valley on the one hand and Fall Creek valley on the other; apparently ice-front waters had free drainage. These kame hills, therefore, have a topographical location that suggests quite a different genesis from the kame areas already described in, or adjacent to, valleys. Again, about one-half mile northeast of Morse Mill there is an extensive deposit of kame drift; and the water-laid moraine continues northward, but not so well developed, into the next sheet.

(6) *Eskers.* On this sheet two general types of eskers exist: (1) Those due to local topographic control; these are short, usually transverse to the direction of the valley axes, starting on one wall and terminating not far from the foot of the slope; (2) The other type appears to be less influenced by the minor details of relief. A full description of eskers appears in a later section.

(7) *Flood Plain Deposits.* These deposits are of two types: (1) Valley trains, the form developed in narrow valleys between morainal loops. In the valley of Fall Creek, and in a portion of the Moravia-Freeville valley, the valley trains attain typical development; they are discussed in detail later (p. 392). (2) Outwash plains noted especially at the wide triangular junction of two or more valleys where the several distributaries from the ice-front built up individual fans which coalesced into outwash plains. A few areas in the uplands have also been noted, bearing this same type of drift.

(8) *Lake Bottom Deposits.* The high-level lakes, held by the ice in the topographical basins of the sheet, are marked by a

veneer of lake sediments, which is not constant and its localization is somewhat puzzling. Two areas in particular may be mentioned: (1) The triangular section about Freeville; (2) The valley northwards from Locke and Moravia. The former of these has a topographic relationship that upon casual observation seems to offer no basin for enclosing a high-level lake. We recall the discussion of drainage lines in this area: Extending from Freeville toward Ithaca is the wide mature valley of Fall Creek, probably the oldest dissection line in the whole region. This valley, as pointed out by Tarr[14] hangs several hundred feet above Cayuga valley at Ithaca. The controlling ice lobe of the reg on was in Cayuga valley. During one of its retreatal stages, when perhaps its most distal reach was in the area of West Danby, several miles south of Ithaca, lateral tongues extended eastward into Sixmile creek, and Cascadilla valleys, while the eastern side of the lobe had a position northward from Turkey Hill (Dryden Quadrangle) blocking the wide flat-bottom valley of ancient[15] Fall Creek. The general northeast trend of the ice contemporaneous with this halt presumably marked an irregular line towards Cortland. It is felt, furthermore, that the valley tongue which for some time maintained a position at Groton (p. 357) may have been contemporaneous with the early period of this halt across Fall Creek valley in the vicinity of Varna. In connection with this discussion we need to note the possibility of southward overflow for this high level lake. The earliest static water about Freeville overflowed by way of the Dryden valley.[16] This stage was succeeded by others with spillways via Turkey hill, the details of which are given in a later section (p. 415). Even at the time of its highest outlet this lake was not deep. With the presence not far to the north, along the Freeville-Moravia and also along the valley about Cortland, of active ice, causing turbid water, which was the source of this clayish sediment, we have an explanation for the lake-bottom deposits noted in the vicinity of Freeville. The further fact that this clay deposit is more markedly developed in that portion of the triangular area towards Groton is in harmony with the hypothecated position of the ice; in the angle towards

[14] *Am. Geologist*, vol. xxxiii (1904), p. 273.

[15] F. Carney: "A Type Case in Diversion of Drainage," *Jour. of Geog.*, vol. ii (1903), pp. 115–24.

[16] T. L. Watson: *loc. cit.*, p. 292.

Fig. 16. Kame hills south of Benson Corners.

Fig. 17. The corrugated clay surface near foot of west wall of valley south of Moravia viewed from top of loop "I."

Cortland the development of clay is less conspicuous, as the area contains much outwash gravel which I describe in a later section.

The second area of these lake-bottom deposits is not so typical a case. The presence of clay south of Moravia has already been alluded to. While this clay may be interpreted as belonging to a temporary lake, nevertheless its deposition may be connected partially with a static body of long duration. The best illustration of it is found flanking the west wall of the valley near Moravia. Here the clays through slumping have assumed a corrugated form (fig. 17), mentioned in describing the drift of this region. Perhaps the case is not clear as to the controlling cause in this slumping. One would hardly expect such localization of lake clays as this area of slipping indicates. On the opposite side of the valley, however, the massive delta deposits (p. 410) indicate less quiet waters, as well as an additional source of the finer-textured sediments. While elsewhere in the valley only slight areas of this same clay have been noted, nevertheless I did not find such extensive deposits as would necessarily indicate a lake of long duration, carrying in suspension a marked amount of this clastic material; waters impounded along the valley tongue, or a stagnant portion of a valley tongue[17], may have afforded opportunity for its development. It should be remembered, however, that northward from the last moraine (p. 361) loop which is about a mile south of Moravia the valley-bottom obviously is the result of such deposition-work, both clastic and organic, as characterized the latest stages of the high level lakes.

It is felt that the study of these lake clays constitutes by itself a problem for investigation, and that the few facts here contributed barely touch the matter. The longitudinal valleys of Central New York each furnish more or less that should be studied and combined into a more detailed report on this topic.

DRIFT OF THE UPLANDS.

To draw a fast line between a region that would be classified as upland, and the valley area, is not easy. For the sake of discussion, however, we will take for the Moravia quadrangle the 1300-foot contour in general as the line of demarcation, along valley slopes, between upland and valley. On this premises the general

[17] Tarr: *Zeitschrift für Gletscherkunde*, band iii (1908), p. 99.

thickness of the upland drift as attested by 210 well records is 24.6 feet; and so far as 29 borings in the valleys give information the depth of drift in the latter area averages 112 feet. This latter measurement, however, has slight value since in these lowland areas water for domestic purposes is abundant at such slight depth that few deeper borings have been made.[18]

(1) *Ground Moraine.* Under this heading is included the glacial débris of irregular thickness covering the intervals between accumulations that mark more permanent halts of the ice. From a study of the areas over which the ground moraine is thinnest, it appears that the topography is an active factor in its distribution. Between the longer dissection axes of the localities where the drift is thin, and the direction of striæ is a pronounced parallelism.

This veneer of ground moraine presumably represents the load of rubbish carried by the ice that remained when the ice covering these areas, in no case very extensive, had become sluggish or stagnant, plus any sub-basal drift already accumulated. So long as active feeding persisted, the front of the ice probably maintained more or less fixed positions particularly in the region of lower altitudes, the valleys. It appears, therefore, that the normal outline of the ice-front in the Moravia quadrangle was serrate, the divide between the longitudinal valleys being ice-free while lobes and tongues occupied the intervening low areas. This ice-free condition of the higher regions probably followed a brief period during which stagnant or semi-inert ice covered the recently freed area. These were periods of less active feeding when the melting factor was much the stronger. The ground moraine consists largely of such a load of rubbish as this static ice contained. Where, however, in certain upland localities we find thickened drift, it is evident that the ice receded more slowly in consequence of much less inequality between the feeding and melting factors, the melting factor being slightly ascendant. In such areas it is apparent either that the ice retreated slowly, or that it contained a very large amount of rubbish. So far as the investigation has proceeded we have not been able to find in the topographic environment itself a plausible control for thickened drift of the uplands.

[18] The extremes for the well records below the 1300 contour are 45 feet and 300 feet 6 inches, neither of which reach rock; above this contour the extremes are zero and 135 feet.

Some quite extensive areas are particularly free of drift. These generally are regions of active ice erosion. One such locality exists south of Locke, commencing with the 1200-foot contour, and embracing a region of some five or six square miles northward of West Groton. The thin veneer of drift present consists of local stones embedded in an exceedingly slight amount of other drift. Some quite extensive plots are free of any drift, the local rock presenting a bare surface. Another similar locality is found southwest of Moravia, on the ascending slope which is reached by the first road running eastward from the valley. Here the horizon of very thin drift commences likewise at about the 1200-foot contour, and comprises three or four square miles. The description given for the area south of Locke is applicable to this region.

These two areas are typical of several others which are usually found on rock outliers, presenting a prow towards the northwest; in each case the longer axis of the fairly drift-free surface is quite parallel to the general direction of ice movement.

(2) *Terminal Moraines.* As the ice retreated across the Moravia quadrangle its front kept a general northeast-southwest position. The minor irregularities in its front gave rise to the several forms of valley drift discussed above. While the ice stood at a certain place in a valley, and drift was accumulating about the margin of the tongue, deposits were also forming away from the valley, thus registering the position of the ice in the uplands. If after the ice had kept a stationary front for some time, by feeding as fast as it wasted, there followed a period of much more rapid melting, thus causing the front to retreat rapidly, no pronounced accumulation of moraine would be formed; then if this period was succeeded by one in which the feeding and melting of the ice were about equal, thus depositing in a narrow strip all the débris carried by this wasted ice, we would have one more band of moraine. If, on the other hand, we do not have these alternating areas of thick and sparse drift, but instead an almost continuous heavy sheet of drift, which in fact is a wide moraine, we conclude that the ice wasted rapidly but fed on at but a slightly less rate; with such a relation the front of the ice receded slowly, and much débris accumulated.

The peculiar feature of the ice-front and the resulting arrangement of the drift in this quadrangle is its direction. The Cayuga

valley is wide and deep; for this reason a lobe of ice reached into this valley, extending far in advance of the front of the ice-sheet. But this valley itself is near the center of a greater basin, occupied by the Finger Lakes included between Otisco lake on the east and Canandaigua lake on the west. The effect of this Finger Lake basin on the general outline of the ice-front is well shown in Chamberlain's map of the terminal moraine of the "Second Glacial Epoch."[10] The proximity of such a deep valley just west of the Moravia sheet, and the fact that the southern half of this valley trends to the southeast, together with the fact that the sheet lies in the eastern half of the Finger Lake basin, accounts for the general northeast-southwest direction which the ice-front maintained as it gradually withdrew across the area.

While it is easy in the principal valleys of the sheet to map the longer halts of the ice as indicated by the loops, there was much uncertainty in definitely correlating the drift of the uplands with these loops. Two reasons particularly contribute to this condition: (1) The uplands contain irregular relief; in consequence the ice-front was also irregular, assuming new positions more frequently than in the valleys. (2) The work of marginal streams tended to blend the drift of these shorter halts. West of the Freeville-Moravia valley, there is slightly more system in the moraine; also in the southeast corner of the quadrangle distinct moraines were mapped.

In certain localities the moraine is characteristically developed. I will describe some of these, attempting at the same time to correlate them with general changes in the position of the ice; plate XII gives hypothetical chronological positions of this ice-margin. But the following discussion does not always consider the moraines in their supposed order of origin:

(*a*) The high points in the extreme southeast corner of the quadrangle were the first of the sheet to be ice-free. A beautifully developed moraine skirts these slopes. Between it and the westernmost of the hills the drainage from the ice-front escaped. In places this moraine is kame-like; one well gives a record of 70 feet mostly of gravel.

(*b*) Following this halt of the ice a second position is indicated by a belt of thickened drift commencing east of Mud Pond and

[10] U. S. Geol. Surv., *Third Annual Report* (1883), plate xxxiii.

ranging in altitude from 1240 to 1340 or 1350 feet. This moraine bears southward for a couple of miles and then directly south continuing along the hills east of Dryden in the Dryden quadrangle. In this distance its upper margin drops about 50 feet in altitude. In texture. so far as revealed in scattered sections, clay predominates, though areas of washed drift are not uncommon. The most marked development in this belt is attained nearer the edges of the quadrangle, the thinnest portions being found in the segment southeast of Malloryville. In the north part, or near Mud Pond, the belt blends with the kame deposits already referred to, the only distinction being in the texture of the materials; but southward there is no ambiguity as the drift both above and below the band is very thin.

(*c*) The great areas of kame moraine in the valley northeastward from Freeville probably indicate a slow retreat of the ice. A lake ponded in the Dryden valley reached into this area; the prevalence of the kame drift is partly due to this fact. East of McLean there is an extensive flat surface in the valley which suggests the burial of a stagnant mass of ice;[20] this mass was left as the high region just north appeared above the ice which afterwards fronted in Fall Creek valley. But south of McLean the retreat was gradual. At and west of Freeville there is a region of two or more square miles from which the ice appears to have withdrawn quickly; it is not improbable that a subdued moraine topography here may have been modified first by lake deposits and later by stream erosion. At any rate, in the valley itself, the first evidence of an ice-halt succeeding the loop south of the Junior Republic is one-half mile north of Freeville, where the slight development of the loop indicates a short halt.

From this time on till the glacier had disclosed about four-fifths of the sheet the line of its front trended southwestward. South of the parallel of Locke, the area between the Owasco Inlet and Fall Creek valleys is almost continuously buried by morainic drift from 20 to over 130 feet thick; there are three small outliers on which the drift is thin, but the surroundings are morainic. I was unable to definitely correlate much of this drift with halts in the valley south of Groton; the map gives one interpretation. But the Groton loop is part of a sharply developed

[20] Tarr: *Zeitschrift für Gletscherkunde*, band iii (1908), p. 98.

moraine which reaches across the sheet. Northwest of Groton this loop leads into a wide moraine the southern part of which may have been deposited when the ice extended a little farther south in the main valley; this drift blends continuously with deposits west and northwest. Where the highway leading east from West Groton crosses this drift it has a kame topography; for about a mile southward washed drift characterizes the belt. Crossing the slight valley of the brook which leads southeastward through Pleasant Valley to Peruville this moraine forms a low ridge or loop. Its continuation from this point is marked by the kame hills indicated in the irregularity of the 1400-foot contour line on the south wall of this valley.

At Benson Corners this moraine shows a variety of development. North and a little west of the Corners it assumes a ridge-like form, the axes having a northwest-southeast trend; while south of the Corners the drift has a typical kame aspect. This kame topography continues in a southeast band to the headwaters of Mill Creek, where a conspicuous ridge of drift crosses the valley indicating an earlier halt of the ice which is farther defined by the outwash gravel spread to the southeast; this ridge rises on the south wall of the valley to the 1280-foot contour, and the moraine, noted in line with a continuation of this ridge, crossing the higher area to the southwest, is another indication of this temporary position of the ice; drift of contemporaneous origin is found in the vicinity of the third south-leading highway, east of the southwest corner of the sheet.

It is apparent that this moraine is complex in development because the ice was gradually retreating with temporary halts. The two temporary halts already mentioned represent the protrusion of ice into low upland valleys, namely, Mill Creek valley and that of the Pleasant valley stream. These two variations indicate slight time periods, preceding the more permanent position which caused the major development of this moraine, which correlates more nearly with the Groton loop.

Returning, then, to the kame plexus south of Benson Corners, we note that this band of drift takes a direction to the southwest where it again has a very kame-like appearance (fig. 16), in the vicinity of the highway-crossing approximately one mile southwest of Benson Corners. Here the ice-front held an east-west course for about one-half a mile, continuing thence in a line

approximately south-20°-west. The drift ridge which marks the latter position is followed by a highway, the second north-south road east of Asbury; it is also indicated by the contour line. This moraine continues in the general direction already mentioned southward leaving the sheet. The sharpest development of the ridge is in the valley east of Asbury; nevertheless the line of drift may be traced southward up over the rock salient, which has an altitude of 1120 feet, thence down the south slope of this hill, where the drift becomes more kame-like and blends into the accumulations of the Dryden sheet.

The ice apparently kept this general position for a time after the valley tongue had withdrawn from Groton, for this moraine continues, when traced northward, into Cayuga county, blending with valley drift west of loop "F" (p. 358).

I would allude again to the fact that this moraine shows clearly the control exercised by the Cayuga valley lobe on the ice-front in this part of the Moravia quadrangle. The irregular course of the drift belt is not so perplexing when we consider the topography of the Genoa sheet in connection with that of the Moravia quadrangle. This is further evidence that the particular form assumed by the margin of a receding continental glacier reflects the local topography to a much greater extent than the general topography of the area farther northward.

The eastern segment of the Groton loop continues northward; but the whole region east and northeast of Groton is such a morainic complex[21] it is quite impossible to map particular halts except where a minor protuberance of the ice has stood across one of the upland valleys from which it retreated rapidly, as south of Summer Hill, and again west of this place. The greatest established depth of this drift is 135 feet, a well record on the Summer Hill road at the farm of A. C. Ranny, and this well does not reach rock; directly south of this well, on the next road, rock was reached at 85 feet. The last position of the glacier associated with the moraine under consideration is indicated by a band of drift, in places one-half mile wide, extending to North Summer Hill where a stationary position of the ice-front is indicated by both the heavy hummocky moraine and the drift loop.

Eastward, the ice reached south in crossing the lower area about Lake Como; a very distinct terminal moraine was developed

[21] Tarr: *Bull. Geol. Soc. Am.*, vol. 16 (1905), p. 223.

contemporaneous with part of the moraine discussed above; this will be described next.

(*d*) Extending northward from the vicinity of Como the 1700-foot contour marks the general course of another of these distinct bands of drift. The arrangement of the moraine east of Como has already been referred to in connection with the valley deposits; the valley east of Como contains much drift. Its association with the moraine northward is not entirely clear, though it seems evident that part at least of the drift in this short valley is contemporaneous in origin, i.e., that for a few miles here the front of the ice was nearly north-south. The hill just northeast of Como, which reaches an altitude of 1700 feet, is in the main drift-covered, part of which is elsewhere described as nunatak deposit (p. 388), an explanation not essentially at variance with moraine interpretation of the drift to the northward; I have frequently noted evidence of these briefer positions of the ice preceding a longer halt. Near the ice-front channel leading into Skaneateles Inlet valley this drift assumes a rather kame-like phase; in this northern portion the heavy part of the moraine is rather narrow and thins both up and down the slope. Along a line paralleled by the highway southward from the entrance to the Skaneateles overflow channel the drift again thickens; it is probable that this represents another halt of the ice following a short period of greater melting or of less activity.

Between this valley and the Dresserville valley is a long divide, rising more than 300 feet above either valley. That the ice moved from the west across this high ridge is shown by the arrangement of the moraine just described. On the west slope of the valley extending north from Como there is very little drift, while moraine is sharply developed on the opposite slope. At the northern end of the valley there is evidence that at a later stage a slight tongue of ice reached a short distance southward.

Contemporaneous with the development of this moraine a dependency from the ice-sheet reached south into the Skaneateles Inlet valley even beyond the margin of the Moravia sheet.

(*e*) Morse Mill and Sempronius lie within an east-west belt of moraine. In mapping the deposits of this area I have appreciated the influence of the Skaneateles Inlet valley, and of the valley between Morse Mill and Dresserville. The proximity of these valleys would tend to increase the development of drift through-

out the intervening divide. The fact, however, that this general development of the drift covers not only the portion of the quadrangle north of Sempronius but reaches also into the adjacent parts of the Skaneateles quadrangle is evidence of a continuous hesitancy in the withdrawal of the ice. Furthermore, even in the most elevated parts of this region, as the hill northeast of Sempronius which reaches an altitude of nearly 1800 feet, the drift is thick and shows a normal morainal-surface development. In these same high levels, the bowlders are large and numerous. It is inferred, therefore, that the ice maintained an east-west frontal position in this part of the quadrangle for quite a long time.

(*f*) The portion of the quadrangle west of the Moravia-Locke valley and north of the tributary rising near North Lansing has a deep covering of drift; only a small part of this is associated with a tongue of ice extending southward into the Moravia valley. From the vicinity of the Owasco Hill to the valley of Hollow Brook is a band of thickened drift, the general position of which is marked by the 1400-foot contour; but towards the southern extremity, the band grows broader and reaches even below the 1300-foot contour. It is clear that the line of drift thus defined is all of the same origin. At the north end, the belt blends into an extensive plexus of drift knolls and ridges that continue along this west slope of the Owasco valley reaching into the quadrangle to the north; at its southern end, it blends into extensive accumulations that encompass both walls of the Hollow Brook valley, being continuous even with the drift which has a marked development at Goose Tree and westward. But the continuity of the belt within these limits points to a relatively permanent position of the ice-front throughout much time. Washed deposits in the form of knolls characterize the whole length of this moraine. In this connection it may be noted that free ice-front drainage probably existed southward through the valley opening out in the vicinity of Locke. This moraine does not admit of definite analysis into positions correlating with the halts in the valley east of it. The longest halt in this upland district is indicated by the moraine which the 1400-foot contour follows southward for about three miles. It is clear that the ice receded very slowly and that it was well burdened with débris. The loops of drift in the valley north of Locke were found to be poorly developed on their western sides when attempt was made to trace them into the moraine just described.

(*g*) Including some six miles along the western side of the sheet, from North Lansing as far north as the headwater area of Hollow Brook, the moraine is so strong as to suggest a permanent position of ice-front. But its development may be completely interpreted only in connection with the adjacent drift of the Genoa quadrangle. It is probable that by the time this moraine was being deposited, the eastern side of the Cayuga lobe had commenced to develop an irregularity due to Salmon Creek valley. The southern portion of this drift area is alluded to in the preceding section as continuous with morainal development about Goose Tree. The abundance of washed deposits over an area a mile square, north and east of North Lansing, is in keeping with the topography and the relations that the ice-front evidently maintained to this general southward rock slope.

(3) *Nunatak Drift.* The maximum thickness of the great ice sheet was attained far from its outer margin. Various estimates[22] have been made of its depth at several points in northeastern North America. Whatever may have been the depth of ice in any particular locality, it is evident that towards the outer edge the ice sheet tapered to the uncovered region. The condition must have been analagous to the relations of the ice noted now in Greenland where there is a seaward thinning.

The irregular topography, the result of a complex drainage history, would give the decaying ice a more or less patchy surface condition. As the ice grew thinner the highest land areas, if limited in extent, evidently would show through the sheet, presenting bare surfaces designated nunataks, or limited ice-free areas sometimes surrounded entirely, and again partly surrounded by the glacier. It is obvious that when such a point of land has appeared above the sheet, melting in its immediate neighborhood would be increased because of the heat reflected from the bare rock or soil.

So long then as the ice continued in this position in reference to the nunatak, a quantity of glacial dêbris would be accumulated. The decay of the ice evidently was more rapid on the southern exposure of the nunatak; the fact that the glacier in general fed from the north would accentuate this difference in the height of the ice about the exposed hill. There would be a tendency for drainage to carry more or less drift, other things being equal, to

[22] Chamberlin & Salisbury: *Geol.*, vol. iii (1906), pp. 355–58.

the leeward side of the nunatak. On the other hand, superglacial, and perhaps in some cases subglacial, drainage accounts for the accumulation of washed material on the stoss side of some nunataks. It has been noted, furthermore, that the drift development in all cases in the area studied is more pronounced on the west and southern exposures of nunataks.

The nunataks from which the preceding general deductions have been made are grouped as follows: (*a*) In the southeastern part of the quadrangle a hill rises to an altitude of 1810 feet. A study of the slopes of this hill shows on its southern side a quantity of drift which extends usually below the 1700-foot contour. Elsewhere about the hill there is slight evidence of its having continued very long as a nunatak. The general relationship of this hill to the topography to the east and to the south appears to preclude any protracted nunatak period. After the ice sheet had thinned to the level of this nunatak further decay shortly brought above the ice surface, if not beyond its front, the whole region of which this hill is a part.

(*b*) About a mile northwest of the above area is a fairly isolated hill reaching an altitude of 1600 feet. The evidence of drift on the flanks of this slope is more pronounced than in the preceding case. A variation, however, should be noted here, since the association of drift in the region immediately south, where the slope drops down to the 1400-foot contour, suggests that a small tongue of ice may have continued in the area after the nunatak phase of this hill had ceased to exist. The kame and kettle development between the 1500-foot contour and the top of the hill on its southern slope therefore may not be entirely of nunatak origin. Nevertheless, such accumulation of washed drift on the southern slopes of nunataks is normal, especially where the body of water in which apparently the deposit was made endured for some time. The ultimate outlet of the water that gathered in the area under consideration, an ice-walled channel, is indicated by the rock cliff and terrace parallel to the highway leading southwest along the hill directly west of the nunatak described under (*a*). The base of this cliff is approximately 1500 feet and its upper limit cannot be definitely defined now because of post-glacial weathering. In any event the evidence of a slight body of water held up in this basin between the high areas discussed in this and the preceding paragraph is conclusive.

(*c*) Northeast of Como, a hill, which appears to be an outlier of the higher ground still father northeast, reaches an altitude of 1700 feet. The unusual association of drift on the flanks and on the southern end of this hill attracts attention; its western slope bears a collar of drift, using a term coined by Tarr,[23] while the southern extremity of the nunatak bears several knolls of washed material. This association is not a definite case of nunatak deposit for the reason that the area is so intimately connected with the moraine extending northward, already described (p. 386), that the typical conditions for a nunatak may be questioned. It is clear, however, that the topography exercised an active control on the drift in question.

(*d*) Just north of the ice-front channel which leads into the Skaneateles Inlet valley, is a hill 1720 feet in altitude. The topographic relationship here favored the appearance of a nunatak, and the mapping of the drift about this hill proves that the nunatak phase was not of temporary duration. In the Skaneateles valley to the eastward a tongue of ice was present sometime after the general ice-front had retreated northward. With the thinning of the sheet conditions favored a depth of ice to the east for some period of time during which the exposed hill maintained a nunatak relationship. Here, to a degree not noted elsewhere on the quadrangle, the collar moraine is developed. The prow or stoss end of the nunatak bears an accumulation of small kames, while the leeward slope is covered likewise by knolls of washed drift. It should be stated that on all sides of this nunatak, save the west, the deposits are sharply demarcated from the slopes that are practically drift-free. Towards the west, however, the control exercised by the Fall Creek valley has resulted in a continuous development of moraine in which it appears that the drift of nunatak is not differentiated from the drift of the lateral moraine type.

(*e*) Southwest of Moravia, Jewett's hill, which reaches an altitude of 1448 feet, apparently bore a brief nunatak relationship to the ice-sheet. Where the highway, ascending the slope from the north, turns directly to the west, a band of thickened drift is apparent on the surface, and is proved by well records. The other slopes of the hill do not seem to have witnessed the accumu-

[23] *Bull. Geol. Soc. Am.*, vol. 16 (1905), p. 225.

lation of much glacial débris. An obvious reason for this, perhaps, is the temporary position of the ice, as well as the gradual slope of the area to the west.

(*f*) At several other points throughout the quadrangle, one notes in the uplands localizations of drift, more or less kamy in texture, that suggest nunatak relationships. The cases are not always clear enough to warrant this explanation of the deposits. Two localities may be mentioned as typical of these: (1) At Fitts Corners is a pronounced kame area, alluded to in the discussion of kames (p. 376). Bearing in mind the relationship of this region to Fall Creek valley, and noting the topography to the north, there is a suggestion of conditions that probably produced, for a temporary period, stagnant ice to the south, while there existed an ice-free area just northward. The Fitts Corners locality is not sufficiently isolated to warrant the name nunatak; nevertheless the probable persistence of ice about the region afforded the environment that governs the formation of nunatak drift. (2) A further illustration of these areas is the height of land surrounded by the 1700-foot contour southeast of Lickville. The irregularity of this contour, particularly on the north, marks a drift-collar, representing a temporary exposure of this area, while all the adjacent region was beneath the ice.

Parallel Ridges of Drift. In three localities on the sheet I have mapped an unusual parallelism of drift ridges. The most pronounced development was noted east of the highway that extends northwest from Owasco Hill; the ridges here are 10 to 40 rods in length, 15 to 25 feet high, and from surface appearance contain much washed material.

One-half mile north from Lafayette a highway leads east; near the margin of the sheet, and some 80 rods north of this road is another series of these ridges; here, however, unmodified drift is more abundant than in the former locality, but good sections are wanting. In neither case is the characterization as to content very accurate.

A short distance north and west of Benson Corners are several ridges, somewhat parallel, but much broader and less sharply defined than in the two areas already mentioned. The material of these ridges is prevailingly fine, from surface indications. Some have a tendency to broaden and flatten towards the northwest.

The ridges of the first area referred to appear to be constructional in origin; their direction marks the lateral margin of the declining Owasco lobe. This genesis seems less applicable to the ridges of the second locality; here conditions favored stream erosion which may have been a factor. The Benson Corners area apparently represents initially the drift that accumulated in the reëntrant angles where the ice-margin had locally assumed a serrate outline; erosion has later altered these deposits, flattening them in the direction of the slope, i. e., to the northwest.

Valley Trains and Outwash Plains.

Both these forms of drift have to do quite as much with topographical relationships as with the positions of ice halts. In a longitudinal valley having so constant a slope to the north that a continuous ice-dammed lake is held up as the ice tongue recedes, we will not find illustrations of the typical valley train. This form of drift develops best in valleys having a slope away from the ice-front; but an initial iceward slope of the valley may be reversed by the gradual filling of the lake from the ice-contact end. With this topographic condition, then each loop of drift may connect southward with a valley train. In any event there is bound to be some distribution of drift away from the loop, which marks the position of the ice, even when a static body of water rests against the loop being formed. In this case the plain of more or less modified drift will be shorter and evidently also steeper in slope since it will represent the deposition of material held in suspension by the water; and with a continuance of these deposits the grade in this part of the valley would at length be changed, and outwash material be built up normally. A section of deposits made under these conditions would show clay at the bottom grading upward into gravel.

It is observed that Fall Creek valley from lake Como southward offers the only area for the normal development of valley trains. Since the development attained by a valley train is intimately connected with the development of the moraine loop with which it is associated, it follows that we have the most pronounced trains only where the loops are conspicuous. In Fall Creek valley the particular halts of the ice, with one exception, appear to have been brief. The Como halt is characterized by a marked

silting up of the valley floor. To a less extent this is true of a halt immediately south.

In the Moravia-Freeville valley, where we find the best developed valley loops of the sheet, the northward slope that the valley floor has, as explained above, hindered the formation of typical valley trains. In this connection, however, it should be remembered that a valley train having undergone rather active erosion in post-Wisconsin times is apt to be so altered as to lose its more definite aspects. This valley has been subject to erosion by a north-flowing stream during part of the post-Wisconsin interval or at least since the high-level lake in it fell below the Lansing outlet; the present stream here drops 325 feet in 12 miles, a grade of 27 feet per mile.

The level area, which is quite extensive for some distance south of Moravia, is partially the product of delta filling that has constantly followed the receding lake level, and is still in progress just north of this sheet. Another interval of fairly level bottom, just south, cannot with certainty be explained as entirely of valley-train genesis. From Peruville southward, however, where the old valley floor doubtless has a southern slope, we may recognize the play of ice-front streams aggrading to the extent of producing valley trains. This suggestion pertains especially to the ice-front drainage characterizing the halt at Peruville.

The normal conditions for the formation of outwash plains, as described by Salisbury,[24] do not exist on the Moravia sheet. Nevertheless there is evidence particularly in the vicinity of Freeville where we have a very broad valley bottom, broader still no doubt before the kame deposits were made eastward by the retreating Wisconsin ice, of the conditions which here favor the coalescence of alluvial fans of ice-stream origin. The great masses of kame moraine flanking the Freeville-Cortland valley represent a duration of ice-débris accumulation that must have been attended by heavily burdened streams flowing away from the Freeville area. The Junior Republic kames, however, were formed when the ice obstructed the drainage, thus ponding a lake which extended southward overflowing south of Dryden lake; so long as ice blocked the ponded water from escaping westward through Fall Creek valley, outwash gravels developed only as fans into

[24] *Geol. Surv. of New Jersey*, vol. v (1902), pp. 128–9.

the static water. Succeeding this lake stage the heavy ice-front drainage spread gravels southward from the vicinity of Red Mill, and in the valley east of the Junior Republic kame area.

Eskers.

As already noted the eskers of this sheet appear to fall into two general classes, (1) those that are connected with local topography, and (2) those more or less independent of the details of topography. There follows a description of the general characteristics of each of the several eskers on the sheet; their location may be found on plate XII, which also indicates by arrow the supposed direction of the esker stream.

No. 1. This esker originates a short distance southwest of West Dryden. The altitude of this area is about 1200 feet, and the drift, which is rather well developed in the vicinity of this village, attains considerable thickness, one dug well having reached a depth of forty feet without encountering rock; the texture of the material as revealed by this well indicates emphatically a washed-deposit origin; the stones contained in it are generally smooth, and there is considerable sand present. So we have in drift topography about West Dryden a suggestion of conditions that govern kame accumulation.

This esker measures on the Moravia sheet but three-eighths of a mile. Its general direction is south approximately 10° west, and this course continues for some distance on the Dryden sheet, then it turns more to the east. The northern segment of the esker, or that on the Moravia quadrangle, so far as revealed by one section and by surface appearance abounds in finer material. There is no evidence of more than a small amount of coarser stones either on the esker or in its environing drift.

No. 2. This esker has its origin apparently at the first four corners east of West Dryden. For one-half mile its course is due southeast, parallel to the brook that flows towards Fall creek. Then it takes a more easterly course. Farm buildings mark its intersection with the next highway to the east. A few rods beyond this road the esker divides, one branch bearing north and east, while the other takes a southern course passing out of Moravia into the Dryden sheet. The vertical range of this esker is about 140 feet, having a continuous decline.

Between the first mentioned highways the esker attains a sharp and typical development. No other on the sheet displays such a continuity of even meanders; but from the point of division the ridges are lower and more flattened. The eastern of these two divisions breaks up shortly into distributaries which lead into a low flat area of sandy soil, the development of which is hardly ample to warrant the designation "sand plain." While the division turning south is typically developed in a few segments, in the main its appearance is indicative of a subglacial stream which had already disposed of most of its load.

As indicated above, the first half-mile of the esker is without a break. The brook which it parallels, however, then cuts across the esker, taking advantage evidently of a low place in the ridge. Just before reaching this breach in the ridge, in walking along the esker from the northeast, one observes on the west side a tributary ridge not many rods long but attaining considerable height near the place of junction with the main esker. So far as may be determined from the surface, in the absence of fresh sections, the material of this esker is prevailingly fine.

No. 3 (fig. 18). There is considerable obscurity as to the termini of this esker. Kame moraine practically hems the esker in except for a portion of its southern side, and either end of the esker appears to be buried or to be interfered with by the agencies connected genetically with this marked kame development.

The ridge in places approximates fifty feet in altitude, and has steep slopes. Some complexity of the subglacial drainage here is suggested by a tributary ridge from the south towards the eastern end of the esker. As exposed in the railroad cut the esker is rather coarse in structure, indicating the vigor of the subglacial stream. It is felt that in an esker of the proportions evidenced by this there should be a typical development of sand plain. The fact, however, that in all parts of the valley, save where the kame topography abounds, outwash material has leveled up to some extent the natural inequalities tends to obliterate the sand plain structure that may have existed; furthermore this absence of the finer assorted deposits that would indicate a static body of water is evidence that when the esker stream was active the front of the ice had retreated, allowing the drainage of Dryden valley to flow westward, thus terminating the lake stage.

A feature worthy of note in connection with this esker is the

long kettle hole immediately north, mapped on the topographic sheet. It may be stated also that this is the only esker on the quadrangle which is denoted by the contours.

No. 4. The highway leading north from Jones Corners intercepts a brook just before the first road-crossing. Commencing a few rods east of this highway an esker extends down the slope of the valley for about one-fourth of a mile. No development of the ridge was noted to the west of the highway. Since the

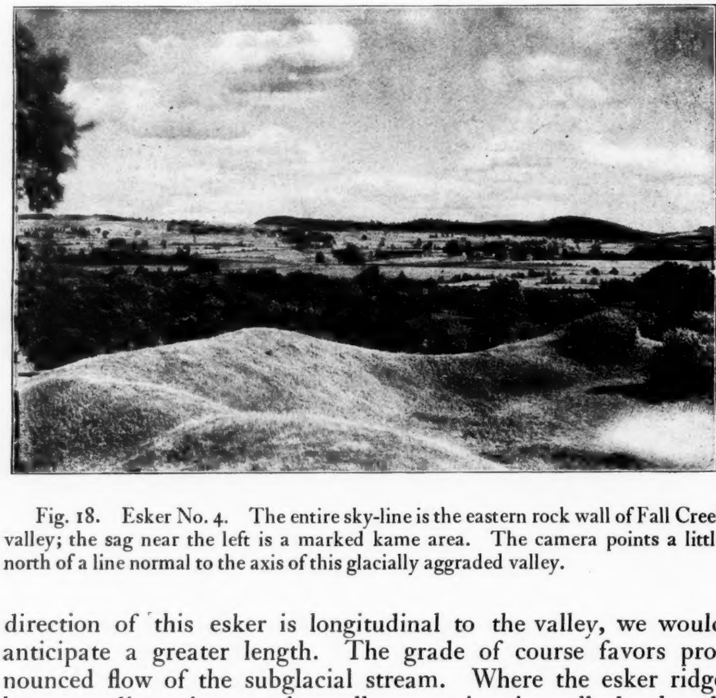


Fig. 18. Esker No. 4. The entire sky-line is the eastern rock wall of Fall Creek valley; the sag near the left is a marked kame area. The camera points a little north of a line normal to the axis of this glacially aggraded valley.

direction of this esker is longitudinal to the valley, we would anticipate a greater length. The grade of course favors pronounced flow of the subglacial stream. Where the esker ridge becomes discontinuous the valley moraine is well develo ed. This fact suggests the possible deformation of the esker ridge by the ice-front deposits. Certain drift accumulations, ridge-like in form, have been mapped as possibly disconnected segments of the original esker. About halfway down this valley an abandoned lime kiln stands on one such segment. About the surface of both

the moraine swells and the esker itself, bowlders are numerous. This is the only one of the four eskers already considered that bears a conspicuous development of bowlders.

No. 5. East of Lafayette is a valley opening northward. The last half mile of this valley before it joins the Fall Creek valley carries an esker, the northern portion of which has attained a very typical development. The esker in the distance over which it has been mapped has an unbroken vertical range of about 120 feet. At the point where the valley widens rapidly the esker swings towards the eastern wall which it skirts for a short distance before it turns to the west into the flood plain section. The valley to the east and south, it was thought, ought to give some evidence of an extension of the esker in that direction; but no ridge exists there. About one-half mile to the southeast is a marked development of low kames probably associated with the esker. Just west of this kame area is an ice-front drainage channel, the stream of which may have removed a portion of the esker.

Northwest, in the flood plain of Fall Creek valley, and in line with the ridge above described, is another gravel ridge which I at first mapped as a separate esker. Its best development is noted near its western terminus where it is about 19 feet high, and its side walls slope 24°. Furthermore, its development here is very symmetrical. To the east, however, it gradually flattens, terminating in low kame knolls. The original development of both the esker and the low knolls of washed material has been somewhat obscured by the great quantity of outwash deposits that are graded down the Fall Creek valley. It is probable that these disconnected ridges belong to the same subglacial stream, and that the gap may be due to both an incomplete initial development and a later partial removal by ice-front stream erosion.

No. 6. An esker, that has a beautifully meandering course, may be seen a short distance south and east of Rogers Corners. This ridge is approximately one-half a mile long. Its southern end has been modified considerably by drainage-dissection, as it reaches to the axis and probably formerly beyond the axis of Fall Creek valley. There is a faint suggestion towards the bottom of the valley of two distributaries though the case is not clear in the presence of alterations or obscurity through outwash deposits. The ridge attains nowhere a height of more than twelve to fifteen feet, and its side walls slope gently. Furthermore in its texture fine material predominates.

No. 7. This esker has its origin on the steep slope south and east of Como. Its vertical range is little more than 100 feet, but its length is scarcely one-eighth of a mile; the esker attains a stout development even in this short distance. Kame deposits are plentiful about the slopes of the hill to the north, and the esker material too consists largely of washed deposits. From the height of the esker and the slopes of its flanks it seems natural that formerly it had a greater linear extent. Just north of this location are accumulations which reach across the valley; the ice fronted along the line of these kames, and the drainage tended to work over the drift deposits immediately southward in the valley. Therefore the wide area of washed drift which now extends southward in the line of this esker has probably obscured, and degraded portions of the ridge. A couple of isolated hills of drift near the middle of the valley, it was noted, are in line with this esker and add to the pertinency of the suggestion.

No. 8. Of the eskers studied on the sheet this had attained the greatest development. The termini of the segments which it is thought represent the original esker give it a distance of approximately five miles. In several places the ridge is completely wanting, one gap at least being normal; this is where post-glacial drainage has cut the ridge.

Faint suggestions of subglacial stream deposits are noted at and slightly above the 1600-foot contour a little northeast of North Summer Hill; a plexus of drift knolls containing a large percentage of washed material exists in this same locality. I am not satisfied that there is any genetic association, however, between this accumulation and the esker. The fact that a gap several rods long occurs immediately to the southwest is the most serious objection to any such association. Where the map next indicates a development of the esker, the ridge is clear and in all respects normal. Then follows a short break, but with enough localizing of drift to warrant making the ridge continuous. From this point on, however, to the last interruption at about the 1600-foot contour southwest, the ridge is strongly and normally developed.

Continuing southwest from the gap in the esker occasioned by the intersection of Dry Run, we find about the 1480-foot contour the same marked development of the winding ridge. After crossing the next highway the esker locally expands into a kame cluster; narrowing down again it continues to the top of the grade where

the ridge flattens and becomes rather indefinite; but to the west of the next public road we come to an elongated ridge that appears to split into two distributaries, both of which turn rather sharply to the south. That these ridges are genetically associated with the esker does not seem proved especially since their continuation north or east is so indefinite. Were the ridges differently oriented we would scarcely consider their association with a subglacial stream, but the direction they take from a line which is continuous with the esker would seem to indicate the influence of more active ice in the Locke valley deflecting the esker stream southward as these ridges point.

In this connection reference may well be made to a geographic influence illustrated particularly in this esker as well as in some of the others. I refer to the location of farm buildings at the intersection of highways with this ridge of drift. Commencing at its supposed point of origin it is noted that every highway crossing save the last to the extreme southwest has been made the location of farm buildings.

No. 9. This esker lies directly north of the southern portion of No. 8. Locally it is referred to by the farmer as the "Indian Road," and the older residents have a legend as to this turnpike of drift having been constructed by the red men. The ridge is indeed scarcely higher than a well made pike, and its course through a swamp area about a half-mile wide is very suggestive of artificial origin. The topographic map makes the slope occupied by this esker much steeper than it really is. As a matter of fact in its whole distance the esker descends northward less than thirty feet, whereas by the mapping it should drop one hundred. The swamp appears to be the result purely of undeveloped drainage lines, as it occupies a flat elevated area including perhaps a square mile. It has been heavily forested, and in lumbering operations the esker is used as a highway.

No sections are present, but judging from the surface it is inferred that the esker material is coarse; in some places the presence of till was noted. No characteristic terminal phenomena were observed; the ridge begins and ends almost imperceptibly. While its course is not straight, nevertheless the curves are few and long.

GENERAL DISCUSSION OF ESKERS.

Location. From the standpoint of altitude we note that Nos. 2 and 3 start below the 1200-foot contour. All the others are higher. Nos. 1 to 4, 6 and 7, descend with the valley wall on which they lie, and terminate, so far as has been observed for those wholly on the Moravia quadrangle, in the flat valley bottoms. No. 5 starts on a flood plain and ascends over 100 feet. No. 9 reaches across a level upland swamp. No. 8, transverse to drainage slopes, is highest in altitude and exhibits the greatest vertical range.

Direction. Nos. 1, 2, 3 and 5 are more or less in harmony with the supposed movement of the ice. No. 9 appears to be opposed to ice movement, while No. 8 is plainly transverse, and Nos. 4, 6 and 7 are somewhat transverse to the line of ice motion. No. 8 exhibits a possible yielding to the activity of the moving ice; by reference to the map we observe that this esker crosses a well developed drainage line which opens toward the general direction of ice motion. The segment of the esker as it crosses the axis of this valley obviously bows in the direction of ice motion. For this reason it is felt that the subglacial stream developed the course indicated by the esker ridge.

Genesis. It is already apparent from this discussion that we are dealing with two types of conditions from which corresponding types of eskers have taken their origin. Nos. 4, 6, 7 and 9, all of which are short and occupy each a continuous slope, evidently were produced in a brief space of time. They represent the transient drainage that became subglacial from a superglacial position, or from marginal areas of ponded water adjacent to stagnant ice which occupied the neighboring low areas, being merely a line of escape of such waters. The conditions are not identical in all of these, but they have in common the location in reference to a valley, and the short linear extension indicating a brief period of formation.

No. 7 originates in a cluster of kame knolls indicating clearly the subglacial course of waters formerly superglacial or marginal. If the point at which this drainage became subglacial had been 40 or 50 rods to the east the course of the resulting esker would have been either south or southeast. The position of the kame deposits in the vicinty of Lake Como is evidence that a large area

of ice extending eastward into the tributary valley became stagnant here. Before the mass of ice had thinned down to a level where "ablation moraine"[25] might gather, thus protecting it from speedy decay, drainage lines were developed beneath it, particularly from the point where marginal or superglacial streams gave a head to the water. Consequently this esker resulted from the escape of water confined between the ice and the high ground to the north and east. The eastward extending tongue of ice here formed a barrier which in connection with the ice in the Fall Creek valley adjacent held up the drainage gathering from the north as well as that coming from the decaying ice. The only outlet for these waters was around the end of the ice tongue, a course which the drainage for some time did take, but as the ice became more and more stagnant the subglacial course was developed. Furthermore, the material of this esker is prevailingly fine, indicating that the chief source of supply was found in the kames where it originates.

While No. 4 is plainly also the result of a gravitative direction given to drainage, the further point of variation in texture indicates different conditions than obtain in No. 7. Here we have no feeding kame area; we have a strong suggestion of coarse till-like material in the esker. Throughout its length, so far as may be mapped with certainty, there is a slight fall, which may account partly for the absence of washed material. Terminally the esker is without characteristic features.

By consulting the topographic map we note that the topography in the vicinity of esker No. 9 favored the development of a reentrant angle of ice-free surface. Thus the ice here formed a saddle; in the sag between it and the rising land south water accumulated. Judging from the present contours, and granting the most favorable condition of this interpretation, such a body of water had slight areal extent and apparently during most of its period did not have a depth of more than twenty feet; but as the ice decayed, it became somewhat larger and deeper. If a stagnant condition of the ice existed for but a short time we may understand how this water found a sub-ice outlet, associated probably with a subglacial stream already flowing southward along the east wall of the valley towards Locke. The slight development of this esker indicates the short duration of the stream.

[25] Tarr: *Zeitschrift für Gletscherkunde*, band iii (1908), pp. 85–88.

Vertical Range. The gradient of an esker-forming stream probably is represented by the vertical range of the esker. In the following data the figures enclosed in parentheses represent the gradient in feet per mile of the esker stream: The range in altitude of esker No. 1 is 100 feet (160 feet); of No. 2, 140 feet (82 feet); of No. 3, 80 feet (80 feet); of No. 4, if we consider only the unbroken segment, 15 feet (60 feet), but considering the scattered segments of the possible former esker the gradient is much sharper, as it trends eastward down the slope; of No. 5, 100 feet (100 feet); of No. 6, 160 feet (320 feet); of No. 7, 70 feet (263 feet); of No. 8 the gradient is broken since it crosses in its length of four and one-half or five miles, one marked valley and one valley of lesser development. The northern segment of this esker drops about 200 feet. Even this distance, however, is broken by the

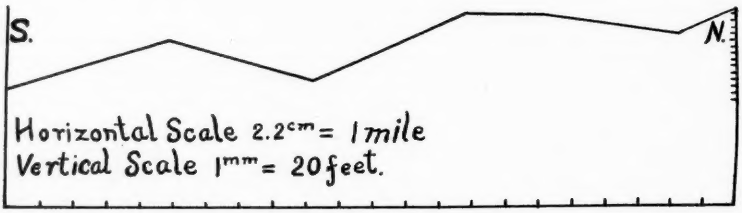


Fig. 19. A profile showing the broken gradient of Esker No. 8.

lesser valley just alluded to. The portion south of Dry Run rises about 120 feet. Fig. 19 plots the grade of this esker stream. The vertical range of esker No. 9 is about 30 feet (46 feet).

From these figures, and the description of the eskers given in the preceding sections, it is apparent that streams of sharp gradient did not develop the highest esker ridges. The low eskers as well as the ridges having low lateral slopes have the higher range in altitude. No. 7, however, appears to be an exception, but as already explained, the lower course of this esker has probably been so altered by outwash material and ice-front streams that the remnant represents but a fraction of the original development, and this remaining portion is the upstream end which has the sharpest gradient; the hypothecated removed segment had a lower gradient. On the other hand, eskers Nos. 4 and 9 have both a

low gradient and a low ridge. The material constituting these two eskers contains a preponderance of coarse deposits; and the former, much till. This prevalence of unmodified drift suggests slight water action.

Esker No. 2 illustrates best of any the typical serpentine course which characterizes the paths of some subglacial streams. The meandering form is also excellently shown in portions of Nos. 3 and 8. It is not well developed in eskers having either the lowest or the highest gradients. A great bulk of aggraded material, it is observed, is present where the sinuous course has a sustained development. Since the esker ridge is developed beneath the ice, the ice-cave being enlarged by ablation as the stream becomes more and more aggraded, the question arises as to the development of meanders. To what extent do the principles accepted as governing meander belts in subaërial streams obtain in the evolution of the sinuous esker ridges? It is very certain that a low stream-gradient does not account for the meanderings of the esker ridges discussed above. I do not believe the meandering of subaërial streams is induced entirely by a sluggish flow.

Ice Motion. The location, direction and degree of development of these eskers, with probably one exception, indicate genetic association with stagnant ice. Nos. 1, 2 and 3 are probably contemporaneous in formation and indicate the interval of inactivity that followed the halt associated with the valley loop south of Freeville. Nos. 4 to 7, which were formed somewhat in the order named, have their genesis with the decaying lobe that reached southward through the Fall Creek valley. That none of these eskers attained a very marked development is due doubtless to the rapid decaying of this inactive ice. Esker No. 9 likewise represents the brief duration of a subglacial stream; the esker ridge is low, and its material, as already mentioned, contains a large amount of coarse ingredients, both characteristics indicating an inactive flow of water.

The only esker on the sheet that suggests a genesis not immediately governed by the underlying topography is No. 8. This ridge represents furthermore a considerable activity of the ice; brief mention has already been made of this fact. The middle portion of its course, which is convex to the southeast, is supposed to be normal to a line of the more vigorous ice which occupied the trough of Dry Run. It is supposed that the whole region was

then covered with ice, and that the subglacial stream had its course marked out shortly preceding the period of subdued activity when the ice on the higher areas to the south and southeast disappeared completely. The manner in which the southwest portion of this esker shows some southward deflection seems also to indicate the activity of the ice still remaining in the Moravia valley.

Conclusion. (*a*) As to distribution, these eskers illustrate the usual association between slopes and streams. Nos. 2, 4 and the southern part of No. 5 are quite parallel to the axis of the valley which each follows. Nos. 1, 3, 6, 7 and 9 course down valley walls of moderate slopes. In the case of No. 3, however, the valley-wall control is not so obvious. This esker probably trends north of the course which the rock slope, here deeply buried, would give it.

(*b*) In reference to degree of development, those eskers having the slightest gradients are most pronounced, both in bulk of deposits and in sinuosity of course.

(*c*) As to cause, it is apparent that the eskers of this sheet are due to an association of inactive ice and relief. In the absence of valleys and plains of marked gradient, eskers would be much less common, as they would then represent the subglacial outlets of superglacial waterways. Stagnant, or slightly active, ice appears to have been the principal factor associated with the eskers of the Moravia quadrangle.

Bowlders of the Drift.

Composition. The most conspicuous of the glacial bowlders seen in the Moravia quadrangle consist of crystalline rocks carried in from the Canadian or other northern areas. Bowlders of local and neighboring sedimentary rocks were likewise noted. On the west wall of the valley just south of the moraine loop "F" (p. 358), many Oriskany sandstone bowlders may be seen; now and then an Oriskany bowlder was noted elsewhere on the sheet, but nowhere else were they numerous enough to attract attention. So far as I am aware the nearest outcrop of the Oriskany formation is found in Cayuga valley east of Union Springs. Small bowlders and pebbles of Medina sandstone, while not plentiful, may be found especially in the sections of kames.

Of Local Origin. In a few localities bowlders of local origin are so conspicuous that special reference should be given them. For a few miles north and a mile or so south of Lickville, a region where the drift is thin, the percentage of local material is very large. Bearing in mind that the general movement of the ice here was from the northwest, and noting on the topographic map the rock salients southwest of Moravia, we understand how the

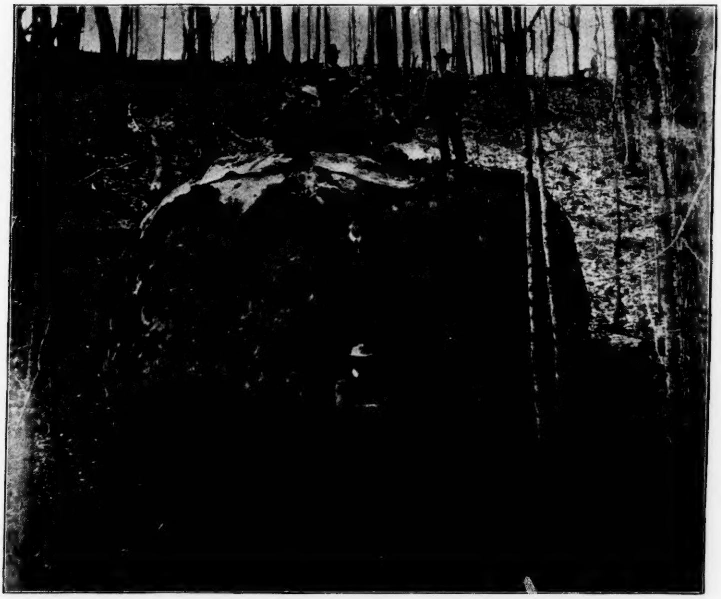


Fig. 20. A bowlder clinging to the steep west wall of Skaneateles Inlet valley.

moving ice took on such a load of local débris. Again, south of Locke, where the altitude reaches 1200 to 1350 feet, the large amount of local material in the drift is evidenced by the stone fences, as well as by the great heaps of stone gathered in tilling the land. Other areas, both of ground moraine bearing a high percentage of local bowlders, and of accumulated drift deposits likewise large in its amount of local sedimentary rocks, were observed on the sheet, but the two localities mentioned are typical.

Crystalline Erratics. A few areas where the foreign element of the drift is large, and the individual bowlders also of unusual dimensions, will be referred to. East of the highway leading northward from Sempronius several very large crystallines may be seen; at the head of the short valley extending westward from Locke, the drift knolls are dotted with erratics; about one mile northeast of Benson Corners, at the general altitude indicated by the 1400-foot contour, the bowlders are numerous and large. Another area of abundant foreigners is the slope of the hill southeast of Como; a Bench Mark of the United States Geological Survey has been fixed in a large bowlder in the field a short distance from the highway which skirts this slope.

A few bowlders conspicuous because of their unusual size were located. Near the first house on the west side of the road north of the Tully limestone ledge, which is crossed by the highway leading northward from Moravia, is a granite bolder showing 10½ feet by 8 feet by 4 feet above the ground. On the farm of S. C. Gooding, about a mile east of Groton, is another very large bowlder. The largest bowlder found in the quadrangle may be seen on the steep western wall of Skaneateles Inlet valley in a wood lot belonging to E. Griffin; its location is a few rods south of the overflow channel (p. 432) which has incised this west wall. The size of the bowlder may be judged from fig. 20.

Ice Dammed Lakes.

Some of the high level lakes of this quadrangle have been studied by Fairchild and by Watson. Their study has been particularly along the line of correlating deltas and locating overflow channels. They mention old deltas at Moravia and in the vicinity of Locke.

Plate XII refers by letters and dotted outlines to the several high-level deltas of the sheet. I will discuss these deltas in the order in which they are designated.

"A." The village of McLean is built mostly on a delta (fig. 21) the altitude of which is about 1120 feet. The southern segment shows the best development, as northward these gravels have suffered much from post-Wisconsin stream work. The lake in which this delta was accumulated evidently was of short duration. It is remembered that southwest of this area, towards Malloryville, the valley is completely blocked with kame moraine;

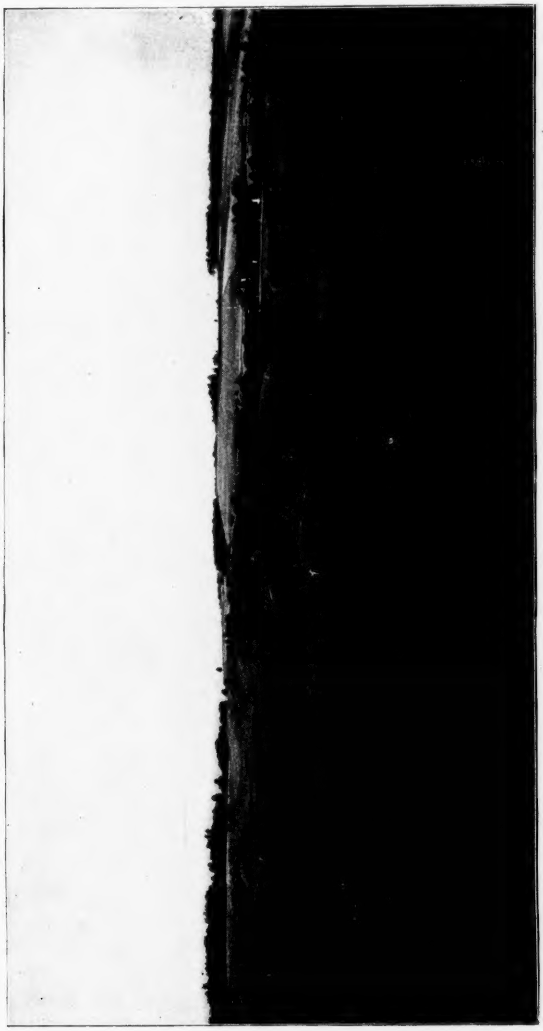


Fig. 21. Kame deposits in vicinity of McLean. Delta "A" shows near right side.

the present course of Fall Creek between these villages is an indication of the irregularly deposited drift that there fills this valley. This lake, if it persisted long enough, must have tended to level off the drift hills approximating its altitude.

"B." This delta is about one mile north of Groton on the east side of the valley. The triangular area marked off by highways lies entirely within the delta. Its slope is gentle, rising from about 1010 feet at the margin to 1035 feet eastward; its area is approximately a square mile. As the lake in which these sediments were laid down gradually lowered, the delta-forming stream from the east evidently hesitated between two courses. Along its eastern margin running southward is the course of a temporary waterway, while the final course taken by the stream from the east has dissected the northern portion of the delta. Thus the body of the delta has remained intact. (Fig. 9).

"C." This delta is adjacent to morainal loop "F" (p. 358); it lies on the same side of the valley, but one and one-half miles north of "B." Its general level is 1120 feet. Along its northwestern side there is an ice-contact slope; here also clay is abundant in the delta plain. In genesis, then, this delta is closely associated with a halt of the valley tongue. Further consideration, however, is given this point in the section where I discuss the static bodies represented by these deltas.

"D." This delta is in the valley bottom about a half-mile southeast of North Lansing; it has but slight development, nevertheless it is typical both in outline and in surface slope, ranging from 980 to 1000 feet. The delta was laid down by a stream flowing from the east. Its serrated front as well as the valley bottom to the west contains a conspicuous quantity of sand.

"E." South of Locke is a delta approximating two square miles in area, and ranging in altitude from 855 to 905 feet. Obviously it represents the work of a stream flowing from the west (fig. 22), and the development evidently attained is not due entirely to stream deposition. A few scattered sections, particularly along the eastern margin of the delta, disclose deposits of till, showing that the load of the stream emptied here into a static body has tended to even up the former irregular morainic topography in this triangular area. In this connection I would mention the fact that practically the whole delta surface is unusually stony, attesting the torrential character of both the major delta-making

Fig. 22. Looking southward through Owasco valley from a point, about 1100-foot contour, on the valley wall west of Locke. Delta "E" occupies the central area of the view; its eastward slope is obvious. The present stream from the west flows at the foot of the slope in the foreground, or along northern edge of the delta.

stream and the many short waterways coursing down the steep slope south of the delta. The surface of the delta likewise shows many distributaries. The permanent post-glacial drainage from the west lies at the foot of the northern wall of the valley, skirting the delta; a slight brook also has sectioned its southern portion.

"F." The local gravel pit at Moravia is in this delta, the surface of which averages 885 feet in altitude. Fig. 23 gives a general view of the crest of this delta. Stream erosion near its north side

Fig. 23. Deltas "F" and "G" from west slope of valley. Camera stands about 200 feet above floor of valley. Inlet stream shows in foreground.

reveals till deposits beneath the gravel. This same relation of unmodified drift has been disclosed also by the creek flowing westward from Montville. The village cemetery between Moravia and Montville is located on this delta. No development of it was mapped with certainty south of the highway from Moravia to Montville which follows, for the most of the distance, the bed of an inter-, or abandoned post-glacial stream.

"G." This is the largest delta of the sheet; views of it are shown in figs. 23 and 24. In altitude it ranges from 1010 to 1060

Fig. 24. Looking northeastward along a stream terrace in delta "G." This terrace shows on topographic map.

feet, and because of post-glacial erosion, it has been so dissected by a meandering stream and altered by resulting aggradation as to suggest two deltas rather than one. Nevertheless the genesis of these sediments scarcely allows a compound result.

The portion of this delta lying nearer Moravia presents a beautifully serrated front and very typical top. This part has suffered but slightly from post-glacial stream work. The eastern segment, which is just northeast of Montville, presents a very even surface, but a very abnormal front, if one is inclined to consider it a distinct delta. This front, however, is more likely the product of stream erosion. It still bears a suggestion of meander curves and sloping floodplain reaching away from them (fig. 24).

"H." Southeast of Wilson's Corners is a slight but sharply developed delta. In texture its sediments are very fine. Its altitude, 1160 to 1175 feet, indicates a very localized water body, while its slight area suggests a brief period of formation.

"I." Immediately east of Morse Mill is a small but nicely outlined delta ranging from 1880 to 1900 feet in altitude. This delta also shows genetic association with a local body of water.

"J." This sheet includes in the Skaneateles inlet valley a small portion of a delta, the remainder of which is on the Cortland sheet. As this delta is associated with a stream that lies entirely off the Moravia quadrangle, no study was given it.

WATER BODIES WITH WHICH THESE DELTAS ARE ASSOCIATED.

The general history of the ice-front lakes connected with the retreat of the Wisconsin glacier has been worked out with considerable detail in the St. Lawrence basin area. The minor lakes formed in the Finger lake valleys, as soon as the ice had withdrawn northward from the divides at the southern ends, coalesced ultimately into two more extensive levels, one Lake Newberry with its overflow channel at Horseheads, N. Y., into the Susquehanna drainage basin; the other and later, Lake Warren, with an outlet across the "Thumb" of Michigan into Lake Chicago. (1) Lake Newbury, according to the geologists who have given it special attention, represents the coalescence of glacial lake Seneca and high-level water bodies to the east, principally of the Cayuga and Owasco valleys. (2) The expansion of Lake Newberry, as the Ontario lobe withdrew northward, resulted in a

great areal increase and a drop in its water level of 100 or more feet. The ultimate outlet of Lake Warren was via Chicago, with possibly several intermediate levels due to successively lower channels between the Huron and Lake Michigan lobes; the steps in this history have been described by Taylor.[26] It seems apparent, according to Fairchild,[27] that Lake Warren in its later stage may have had also an overflow to the east as the ice withdrew gradually to the axis of the Mohawk lowland area. Glacial lakes Newberry and Warren are therefore associated with the more general expansion of the ice-sheet. The earlier lakes which progressively united to form these great water bodies were associated with minor lobes that reached southward through the axes of the Finger lake valleys. A consideration of the high-level lakes of the Moravia quadrangle starts, then, with the minor bodies of water which skirted the retreating ice-front.

When the Cayuga lobe reached somewhat south of Ithaca, with one dependency extending into the valley of Sixmile creek, and another towards Newfield, a lake stood in front of each of these minor glaciers, one, Lake Brookton, overflowing by way of Willseyville (Fairchild's White Church spillway), the other, West Danby lake, via Spencer Summit. With the withdrawal of the ice from "South Hill," the salient just south of Ithaca, these two bodies of water coalesced, forming glacial Lake Ithaca, which overflowed by way of White Church. Lake Ithaca endured till the ice had retreated, revealing an altitude lower than that of the White Church spillway; this occurred at Ovid. Lake Ithaca then flowed into glacial Lake Watkins, which escaped southward over a spillway at Horseheads.[28]

The statement has already been reiterated that the region east of Cayuga valley was controlled by the lobe of ice that persisted in this valley long after areas on the same parallels eastward were ice-free. This condition maintained in the Moravia quadrangle a general northeast-southwest position of the ice-front. The study of moraine belts led to this deduction; an interpretation of the high-level deltas further fortifies the conclusion.

[26] *Bull. Geol. Soc. Am.*, vol. viii (1896), pp. 48–53.

[27] *New York State Museum*, Bulletin 106 (1907), pp. 43–44.

[28] The résumé contained in this paragraph is based on the publications of Fairchild. The writer, however, has made a field study of all the localities mentioned.

While it is probably impossible to be certain about the chronology of these deltas, nevertheless in discussing their genetic relations an attempt is made to arrange the associated water bodies in their chronological sequence. In this study only one type of observation has been made in addition to verifying the earlier work of Fairchild and of Watson on the high-level lakes of the region. The overflow channels with which these men have correlated the deltas studied are all located along general drainage lines to the south and west of the water bodies under discussion. After having mapped the bands of thickened drift, one notes that the eastern margin of the Cayuga lobe so abutted the rock salients as to form intermediate overflow levels between the spillways that have already been located. In accordance with these observations the several deltas will now be considered in the order in which it is thought they were developed.

"A." The position of the ice as denoted by the morainic loop southward from Freeville held up in front of it a slight body of water which overflowed through the Dryden valley with a spillway approximately 1207 feet in altitude. This is the first static body of water formed on the quadrangle as the ice retreated. No typically developed delta was observed correlating with it. In the wide valley, however, immediately north of Dryden village may be seen on the eastern wall a well formed alluvial cone which presumably correlates with this level.

But the delta ' A" at McLean, having a general altitude of 1140 feet, obviously represents an overflow channel, one wall of which was the ice itself, the other the northwestward slope of Turkey Hill, located on the Dryden sheet. The water thus had its ultimate outlet through Cascadilla valley by way of Ellis, and thence into the glacial lake that occupied Sixmile creek.

"C." As already stated, this delta is associated with a morainic loop of which it almost forms a part. Its level coincides closely with that of "A," but it is not of contemporaneous development; while these two deltas correspond in altitude, "C" is of much later origin; its position is such that a marked accumulation of aggraded material developed in a fairly short time. The loop of drift reaching across the valley at this point attests a stationary position of the ice for some period during which there poured along the eastern side of this ice-tongue a vigorous stream whose gradient suddenly changed, as may be observed on consulting

the topographic sheet. It is entirely possible that this delta started as an alluvial cone, growing rapidly, and that in the shifting of the ice, a slack or even static condition of drainage developed in the rear of the cone; consequently the final deposition of stream-load produced the delta effect.

"B." The well developed delta north of Groton appears to be associated in its earlier stages with a partial withdrawal of the ice from the west slope of Turkey Hill, thus lowering the outlet while still keeping a static body of water, a score or more feet in depth, over the normal divide of Fall Creek valley in the region of Freeville. But after the ice had retreated sufficiently from Turkey Hill to drain Fall Creek valley southwest of Freeville, then this latter divide became the overflow channel of the water standing in front of the ice in the Groton valley. This spillway is given as 1040 feet in altitude.

"H." With the thinning of the general ice-sheet over the Moravia quadrangle the Owasco lobe alone remained, but preceding the stage when the area of this sheet bore only remaining portions of the Owasco lobe there appears to have intervened a period when the eastern flanks of the Cayuga lobe still spread over a part of the western area of the sheet. Delta "H" represents the withdrawal of the ice from the high area east of Wilson's Corners sufficient to allow drainage from the north an outlet between the ice and this slope into the small body of water held up in the Morse Mill valley; this delta has a slight areal extent, but is typical in the usual delta features. It apparently does not represent a long time interval. Its position and development are both in accord with the ice-walled channel outlet described southeast of Moravia (p. 435).

"I." This delta at Morse Mill represents a lower level of the same slight body of water. Its spillway also was formed by the ice and the westward slope of the salient southwest of Moravia.

"G." The portion of delta "G" here referred to lies northeast of Montville and has a general altitude of 1060 feet. In accordance with the distinction made by Fairchild[29] this delta represents glacial Lake Groton which overflowed through Fall Creek with a spillway at Freeville. The great mass of material in this delta bespeaks the vigorous drainage of ice-front streams

[29] *Bull. Geol. Soc. Am.*, vol. 10 (1899), p. 50.

coming from the north. During the formation of this part at least of delta "G," the ice of the Cayuga lobe obviously reached eastward from Ludlowville covering a later overflow channel at North Lansing, covering also the Moravia sheet northward, and connected apparently with the morainic belt east of Asbury. With this tendency of the ice, it is probable that the duration of the Freeville overflow channel was contingent upon the position which the eastern margin of this Cayuga lobe maintained in reference to the high area south of Asbury, that is, the rock hill in the southwest corner of the Moravia quadrangle. When the ice crept down this western slope, disclosing a contour lower than 1040 feet, it is evident that the waters of the glacial Lake Groton worked along the edge of the Cayuga lobe and flowed into glacial Lake Brookton. The western slope of this hill shows the effect of such a spillway.

As just indicated the water level connected with delta "G" gradually dropped to an overflow of about 1020 feet, which we will call the Asbury spillway. In consequence, this delta has a lower stage during which it developed westward from the part above described; the feeding stream, when the lake-level fell, took a course near the western part of the old delta. The difference in level between these two parts of this delta is shown in figure 24. The highway leading south from Asbury for some distance passes over a rock surface from which the normal veneer of drift has been largely removed by the outflowing waters of this lower stage. It is evident that this relation of ice and topography south of Asbury was maintained for considerable time, a position of the ice probably marked by drift loops in Fall creek valley on the Dryden sheet.

"D." This delta, meagre in development, apparently also represents an overflow by way of Asbury; its altitude is about 940 feet. Furthermore, it seems to mark the critical stage in the history of glacial Lake Ithaca, a stage that immediately preceded the formation of Lake Newberry. This delta is a short distance west of the Lansing overflow channel, and was developed during and shortly after the time when static water stood over the channel. Its height and areal extent both indicate a brief duration of the water body which it is associated with.

"E." The Locke delta, as already pointed out by Fairchild[30]

[30] *Loc. cit.*, p. 50.

and by Watson,[31] represents the level of Lake Warren. Its general altitude is 865 feet, but it blends westward into slopes, alluvial cone or delta in origin, that suggest a gradual lowering of the waters from the Lansing overflow channel. The sharper development of the delta, however, is associated with the lower level.

"F." Delta "F" correlates with "E" at Locke. More recent erosion has removed much of this gravel from one-half of the valley as far upstream as Montville. Post-glacial stream-work also has creased the northern slopes of the delta, revealing buried drift which often is very bowldry. The top of delta "F" has a gentle southward gradient. Both this fact and its frontal outline indicate a rather speedy decline in the level of the Lake Warren waters. Figure 23 gives an idea of the general outline of the delta viewed from the west wall of the valley.

Smaller Deltas. The above list includes the more conspicuous areas of delta gravels. Each level thus indicated marks also the altitude of many minor accumulations of gravel at the mouths of secondary streams. These smaller deltas are particularly common along the Freeville-Moravia valley. A delta fan of considerable size shows at Peruville, and apparently correlates with the lake level indicated by deltas "A" and "B", overflowing by way of Turkey Hill. South of Locke, on the eastern side of the valley, several of these minor deltas show. Another marks the outlet of Dry Run, south of Moravia.

Other Lake Phenomena. The dimensions of some of these deltas, particularly "G" and "E," suggest a static body that endured for some time. When, however, we consider the torrential condition of drainage incident to the retreating ice-sheet, and the fact that load was easily acquired by all streams, there being little vegetation to retard degradational agencies we realize that in a relatively short time a great quantity of gravel accumulated at the mouths of these streams. Consequently the other shore phenomena which we are accustomed to connect with water bodies did not attain much development in this quadrangle; some of the lakes had a brief existence; some were so slight in area that very little wave work was accomplished.

In the valley south of Moravia, also in the neighborhood of Lake Como (fig. 15), and again southwest of McLean was noted the

[31] *Loc. cit.*, p. 193.

general flat-topped appearance of many drift knolls. These flat tops correlate with water levels; originally they projected somewhat higher, but probably never very far above the range of wave work, and therefore were leveled off.

Along the Freeville-Moravia valley I observed on drift slopes some benches that apparently correlate among themselves, forming different levels, suggestive also of wave and current work. These benches show to best advantage in the spring of the year when snow persists longer in the angle between the cliff and terrace.

Just south of the mouth of Dry Run are two terraces cut in the rock. These are the only instances of terraces in rock, possibly produced by waves, which I noted in the quadrangle. One of them corresponds to a lake level. In the absence of other such terraces, I would not interpret these as due to wave work.

No bars, spits, or other phases of shore gravels, were noted. The period during which these lakes stood at any given level hardly sufficed for phenomena of this type.

Post Glacial Tilting. Up to this point no reference has been made to the changed altitudes given these deltas by tilting subsequent to their formation. The value of this factor for any particular gravel terrace varies directly with its distance north of the spillway used by the static body in which the terrace was constructed. The first data referring even indirectly to this deformation have been supplied by Dr. G. K. Gilbert who estimates that the postglacial tilting of the Iroquois shore line, in this part of the state, is 2.7 feet per mile.[32] Only on the assumption that no land warping took place in this area during the time that intervened between the formation of the deltas we are discussing and the development of the Iroquois shore line does this factor apply. On this assumption, then, it follows that the highest delta at Moravia, constructed in a water body which overflowed by way of Turkey Hill, is now approximately 42.9 feet higher than when it was formed. The assumption of stability of the land surface during the interval between the Turkey Hill overflow level and the level of glacial Lake Iroquois is too remote to give these figures much value. It is reasonable to assume that the levels existing while these higher deltas were being constructed, because of sub-

[32] Quoted by Tarr: *Jour. of Geol.*, vol. xii (1904), pp. 79–80.

sequent pre-Iroquois land warping, intersected the water-level which developed the Iroquois shore line. This suggestion would merely call attention to the futility of applying the measure of land tilting established through a study of the Iroquois shore line to the water levels of antecedent lakes.

Alluvial Fans. Some alluvial fans connected with higher water-levels have been noted. One, particularly well-developed, exists at the mouth of the valley into which esker No. 3 leads (p. 395). Another is connected with Hollow Brook, southwest of Locke. The over-deepening of the Owasco valley by glacial erosion has favored the construction of alluvial fans now noted near the flood plain; north of Moravia, on the west side of this segment of the valley each house, along the valley road, stands on such a fan; some of these are conelike in steepness. A few fans are found also on the east side of the valley.

Glacial Erosion.

As in all glaciated areas, the round-topped hills (fig. 18) of the higher altitudes in the Moravia quadrangle suggest the erosive work of an over-riding ice sheet. The details of this process imply both abrasion and plucking as the ice closing about the elevations first modified them through freezing to and transporting the blocks already loosened by weathering processes. It is probable, however, that the tendency of over-riding ice to modify the higher points into rounded domes cannot work itself out typically save in areas of crystalline or other rocks of homogenous structure. Regions of sedimentary rocks, particularly where the beds are thin and somewhat irregular in structure, do not have the nicely rounded domes that elsewhere indicate ice-carving.

Looking southward from a position well-up the valley wall near the foot of Owasco lake one sees most convincing evidence of the power of ice as an agent in altering valleys. While the valley seems wide, and the upper part of its walls have a slope corresponding to the age indicated by this width, yet the depth of the valley is all out of harmony with these characteristics. The gentle slope of this upper part of the walls changes suddenly to a declivity, continuing steep down to the flood-plain. At, and north of, Moravia on both sides of the valley the highways ascend these slopes only by laboriously swinging far to the right and left while

making relatively a slight ascent. And for several miles at a stretch no roadway-construction has been attempted. The vertical measure of the steep part of the side walls is 300–500 feet, but we have no proof of the amount of glacial over-deepening in this valley; the deepest well, 200 feet, is near the east wall of the valley at Moravia and did not reach rock; a conservative estimate of the measure of glacial erosion here would be 1000 feet.

These steep walls are remarkable, but their continuity, giving the valley a canal-like effect, an artificial appearance, is more remarkable. Rivers widen their valleys by cutting alternately against the two walls; thus we generally find a steep slope directly across the valley from a gentle slope; a long-range view through such a valley is broken by spurs each hiding the end of the next one beyond but belonging to the opposite valley-wall. Glacier ice is the only agency known to smooth and straighten the sides of a valley.

When glacial erosion thus alters a valley, deepening it and cutting back the lower parts of its walls, an abnormal relationship is established between the major and tributary streams; the latter, instead of flowing into the former at an even grade, drop over falls or tumble down cascades in many instances several hundred feet. The immediate base-level of a branch stream is the main stream, and save in very exceptional cases the branch lowers its bed in unison with the major. But after a valley has been glacially over-deepened the tributary streams commence to adjust themselves to the new base-level, and in consequence have cut rapids and gorges; these tributaries then ocupy "hanging valleys." Fall Creek valley in the vicinity of Dresserville, and Skaneateles Inlet valley also show the result of vigorous glacial erosion.

Similar evidences of the work of glaciers have been observed in many parts of the world. That ice has done work of such magnitude, there is almost unanimous agreement among scholars. Of necessity, it is impossible to study the actual process of glaciers eroding valleys. In some mountainous regions at the present time glaciers of the alpine type are at work; the portions of the valley from which such ice has recently withdrawn show plainly what has been done: a U-profile has been developed, making the valley deeper and its bottom broader; the sides and bottom, where bare, show scouring, polishing, and scratching, the work of stones of all sizes held in the basal and lateral parts of the valley glacier.

Hence it is concluded that the over-deepening of valleys is accomplished slowly by the stone tools plowing and rasping the solid rock; the nature of the surface being eroded, the quantity of the tools, the pressure of the ice, and the time through which these continue to act are factors in the process.

The conditions that govern the erosive work of an alpine glacier are probably very much the same in nature as operated in a continental glacier, but the pressure of the ice in the two cases is quantitatively different. The degrading tools are held to their work of erosion by the weight of the ice mass above; for this reason, the longitudinal valleys of central New York were altered by the ice cap. Rock in valleys always sustained a greater pressure than rock of the upland; hence the valleys suffered more erosion, thus supplying the tools for sustained erosive-work. Furthermore the shoe of ice filling the valleys bore down heaviest on the valley-bottom, the pressure decreasing up the side walls as the thickness of the ice also decreased, but not proportionally with the ascent for the reason that the ice-shoe tends to spread laterally under weight. This lateral pressure combined with the vertical pressure produces the U-profile, an erosion-product never arising from the work of water.

Any discussion of conditions that obtained during Pleistocene times must be partly theoretical. In quantity of ice, Greenland affords the nearest approach to a continental glacier; in the interpretation of the features that probably characterized the margin of the Pleistocene ice-sheet, Alaskan studies have been most helpful.[33] The alpine glaciers are strictly analagous to the valley dependencies of the great ice-sheet only when it fronted in mountainous topography. The gradient of the valleys of central New York was generally towards the ice, hence the conditions were quite different from what is seen today in the Alps. It is largely by inference based on such facts as observers have recorded in the above regions, and on the distribution and nature of the drift sheet itself, that we interpret the varying mode of its origin, and reconstruct the shifting outline of the ice-front.

The most conspicuous feature of glacial work is the stupendous erosion seen in some valleys. In other valleys deposition took

[33] Tarr: *Zeitschrift für Gletcherkunde*, band iii (1908), "Some Phenomena of the Glacier Margins in the Yakutat Bay Region, Alaska," pp. 81–110.

place. The variation of valleys from transverse or from longitudinal positions is attended by a corresponding variation in erosion. The Moravia quadrangle has several valleys maintaining various attitudes between the transverse and longitudinal positions. Remembering that the ice in this area did not have a meridional motion, we understand the unequal erosive effects in these valleys. For example, a valley extending southeastward from Freeville bears quite a transverse relationship to ice-motion, whereas certain segments of the more longitudinal valleys (fig. 4) are quite in line with the deployment of the moving ice. The valleys that approach a transverse position suffer modification largely through partial burial. This is particularly the case when they happen to coincide with ice halts.

The development of extended and fairly steep valley walls is not normal to regions having slight vertical variation in stratigraphy. The development of drainage lines, and the resulting disintegration of terranes, produce side walls more or less irregular in reference to the axis of the valley. In a longitudinal view this condition gives the effect of over-lapping spurs.

From Locke northward the Owasco inlet, as already stated, especially on its western side has an oversteepened valley slope such as would not normally be developed in the stratigraphy. On the eastern side from Moravia northward the same condition exists; the exact nature of the valley wall on this side, southward from Moravia, is partially masked by drift accumulations. But this segment of the Freeville-Moravia valley does not have overlapping spurs, a consequence of the active ice-erosion in this longitudinal valley. There is conclusive evidence that the northern half of the Freeville-Moravia valley is genetically due to the same direction of stream flow that the valley now has. This being the case the rock floor had a general northward gradient, and accordingly offered the moving ice the condition of obstruction conducive to a great amount of erosion.

The same principles of ice-erosion in longitudinal valleys is illustrated by the steep rock slope extending from Morse Mill southeastward to the vicinity of Lake Como. Again, in the valley of Skaneateles inlet we have these oversteepened slopes on both sides, so far as this sheet is concerned (fig. 5), due to ice erosion.

When glacial-deposition does not later take place in localities of active glacial-denudation we find barren farms as on the steep

slopes lying between West Groton and Locke; likewise on the two salients southeast of Moravia, as well as several northward sloping areas found on the eastern side of Fall Creek valley northward from McLean. Of a similar genesis too are some scattered areas in the southwestern part of the quadrangle. This condition in the uplands has been discussed as illustrating areas where the till is thin (p. 381). The slopes alluded to afforded the ice the proper obstruction attitude for very effective erosion.

In general, however, the subject of ice-erosion is thought of as applying more particularly to longitudinal valleys. Is the entire transverse profile of a valley altered by ice, or is the erosion confined largely to the lower parts? The observations bearing on this point, made in the Moravia quadrangle, are best illustrated in the Freeville-Moravia valley northward from Locke. As mentioned above, this segment of the valley offered the most favorable conditions for ice erosion. A generalized statement of the conclusion from the data observed is: In this longitudinal valley the most vigorous erosion was operative along the contours below 900 feet. Above this plane is a zone of less active erosion, while still farther up the ice did considerable abrasive work. In the lower contours of the valley, however, the power of an ice sheet to deepen longitudinal dissection lines is very impressive.

The above generalization is based on a detailed study of the slopes, and upland above the 900-foot contour; what the ice did below this general altitude of 900 feet is perfectly clear. Folded beds, rather completely disintegrated, shown in figure 25, may be seen in a quarry a short distance northeast of Locke. The fold as exposed in this cross-section, which is oriented S. 30° east, has a tilt of approximately 51°. The disturbed zone is but a little over one foot in thickness and is made up of thin sandy shale layers beneath which is a sandstone bed about six inches in thickness. The quarry has been opened for removing the heavier beds which are subjacent to this six inch layer of sandstone. Overlying the distorted beds are about two feet of drift and quarry rubbish, the till part of which in all probability is not in place.

Figure 26 shows another folded horizon a mile and one-half north of Moravia. This fold inclines about 36°, and the exposure is in an east-west line. The folded area is on the eastern slope of the valley, and the fold itself is turned against gravity. Here too the disturbed beds, about eighteen inches in thickness, con-

sist of shale and sandy layers. Overlying the disturbed zone is very compact ground moraine from three to four feet thick. It should be stated further that the disturbed beds are underlain by a hard sandstone layer over which the stream is now flowing.

A similar disturbance was seen in a recent stream cut about a quarter of a mile northeast of the folds just described. Here too it should be noted that the fold is turned against the slope.

Fig. 25. View in a quarry east of Locke; shows weathered thin bedded strata folded by glacial ice. The exposed plane is approximately parallel to the last movement of ice.

Origin of These Folds. In other localities it has been noted that freezing and thawing is competent to produce anticlinal disturbances in sedimentary beds. Under normal conditions folds thus produced should be symmetrical and the disturbed beds should blend vertical y into more and more residual soil; a gradual transition likewise should be noted in the opposite direction;

where beds are so deeply buried this explanation is not applicable. The area shown in fig. 26 is below the normal frost line for this climate. Fig. 25 gives a section the upper part of which is subject to frost; there is evidence here of frost alteration in the apex of the fold, but this fold is so unsymmetrical that the frost theory cannot apply.

Folds due to creeping are not uncommon especially in the horizons of thin beds. The factor which induces the disturbance

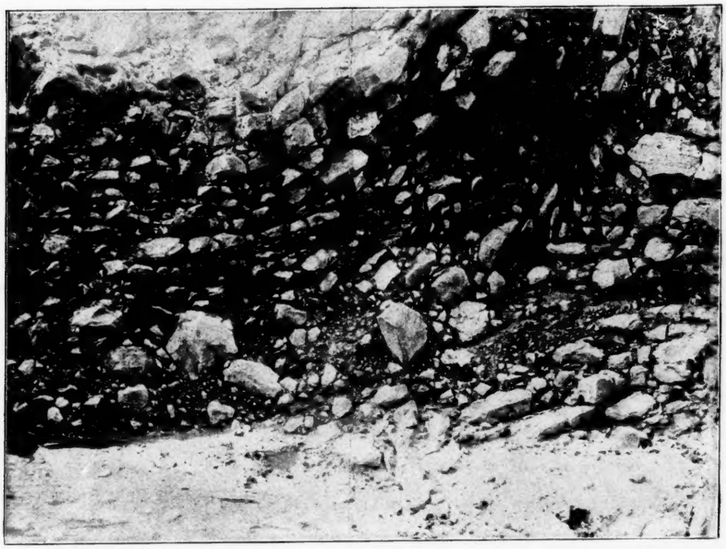


Fig. 26. This view shows subjacent strata disturbed by the outward or lateral motion of an ice-lobe.

is gravity. A fold then which is turned in a direction contrary to the supposed force of gravity cannot be thus explained.

In glaciated countries it is very probable that the superficial rock horizons when removed by glacial erosion and other methods of ice disintegration no longer subject the underlying strata to the normal burden of their weight, and in response to this removed pressure these underlying horizons doubtless buckle, producing a fold. Such folds, however, should always be symmetrical or at

least approximately so, and should likewise show the effects of rather speedy giving away to certain stresses. This type of fold probably is represented in the Moravia quadrangle, one example at least having been noted. But the folds in question cannot be explained as due to buckling.

Campbell[34] has described folds which result from normal weathering of superficial formations. The weathering being localized along joints, there results, particularly when these joints are numerous, a very appreciable lateral extension which at some point in the horizon overcomes the normal pressure and produces a fold. Both the mode of production and the type of fold produced, which in all cases illustrated are symmetrical, preclude this explanation for the folds in question.

The only remaining explanation seems to be that of over-riding ice. We have little data of exact observation detailing the method of ice-erosion. When the country being transgressed bears a mantle of residual soil, this is removed before the less weathered horizons become subject to ice abrasion. Considering the great weight of over-riding ice, we apprehend that friction between its base and the underlying surfaces accounts for the removal of great areas of partially weathered rock. The distorted horizons above figured seem in harmony with such a method of removal. This being the case, then, these folded horizons indicate a zone where ice-erosion has been less efficient.

Fig. 25 shows that the direction of ice-motion was more nearly north-south. Fig. 26, in which the fold is turned eastward, implies a flow of ice in that direction. The former locality, is quite in line with the direction of ice-motion for this region. The latter locality suggests rather a movement of the declining Owasco lobe, when on the eastern side it fed outward from the main axis of the valley. This outward movement of the ice in valley lobes has long been known. These figures therefore illustrate both linear and lateral motions of the Moravia lobe.

The areas shown have been selected from several photographs; some of them, however, represent less distortion.

As already suggested, theoretical considerations point to greater activity of ice as an eroding agent in the lower contours of these longitudinal valleys. On the west side of the valley south of

[34] M. R. Campbell: *Jour. of Geol.*, vol. xiv (1906), pp. 226–32.

Moravia, at an altitude of about 820 feet, a polished and striated surface attests the vigor of the ice action; that plucking was a part of the process of disintegration is evidenced by the several stages of rounded edges, farther down the slope, developed after the removal of rock along bedding planes. The basal load was sufficient for most active planing or abrasive work. On the same side of the valley but northward, similar striated and polished surfaces have been noted. Also on the opposite valley wall, the vigor of the ice is indicated by the well rounded and polished ledges. Southward from Locke, however, evidence of this nature is wanting. In general it may be said that evidence of the most active ice-erosion is not found over 150 feet above the present flood plain.

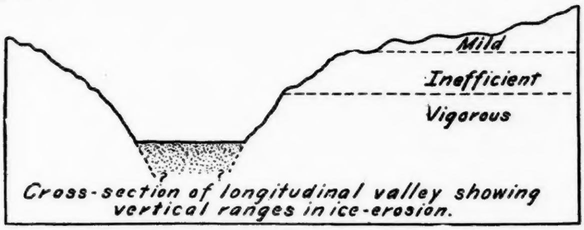


Fig. 27. A generalized representation of glacial erosion in a longitudinal valley. The observations on which this deduction rests were made about the Owasco valley from Locke northward.

The resultant, then, of ice-erosion is to deepen longitudinal valleys, producing oversteepened walls, the horizon of accentuated erosion commencing in the Moravia valley somewhat below the 900-foot contour. Consequently, in cross-section, valleys that preglacially had a sharp V-outline, are given more of a U-shape outline, while mature valleys are made composite by having a U-outline cut approximately along their normal axes.

Fig. 27 attempts to generalize the results of ice-erosion which, in accordance with the above discussion, may be given three ranges showing variation in effectiveness. First, in the highest altitudes, a range of mild erosion; second, next below, a range of inefficient erosion; and third, toward the valley axis, a range of vigorous erosion.

Whether this enormous over-deepening of certain valleys was accomplished by the ice-sheet while the margin was far south,

or by the fringing tongues or dependencies that fed out into the valleys as the ice-sheet advanced and again as it retreated, and whether more erosion was done by the Wisconsin ice than by an earlier invasion, are pertinent questions. Observations made in the Ticino valley of Italy,[35] and in other valleys through which glaciers have fed from mountainous regions, indicate that valley glaciers performed much erosion; but in these valleys the ice moved downhill, whereas in central New York the valleys sloped the other way. Furthermore in New York there is evidence of erosion, as in the Laborador pond valley of the Tully quadrangle, producing a "through" valley where apparently two streams formerly headed against each other. It does not seem to be clearly demonstrated that over-deepening and "through" valleys are the products solely of valley glaciers. Again, if the erosion of the Owasco valley was accomplished by dependencies of the retreating Wisconsin ice we should find drift-loops in the parts of the valley not now drowned by the lake, and in the lake part lateral moraines correlating with loops; on the Moravia sheet I did not find loops near enough to the over-deepened part of the valley to indicate that the erosion was due to tongues of ice appended to the retreating Wisconsin sheet. If an earlier invasion did not extend farther south than the general location of Chamberlin's "Moraine of the Finger Lake Region,"[36] we can conceive how the alteration of these valleys may have been accomplished by glaciers somewhat of the alpine type, belonging to a pre-Wisconsin ice-sheet.

Striae.

The thin drift in many portions of the uplands, and the altitude of the axes of rock salients have made obvious the direction of ice-motion over several parts of the Moravia quadrangle. While many scores of readings were taken in the particular areas, the average of these in most cases has been used in Plate XII which locates the most pronounced striated surfaces.

The glacial scratches we now read represent in the majority of

[35] W. M. Davis: *Appalachia*, vol. ix (1900), "Glacial Erosion in the valley of the Ticino," pp. 136–56.

[36] U. S. Geol. Surv., *Third Annual Report* (1883), pp. 353–60.

cases, the direction of motion of the retreating ice-body; and, as had already been discussed, the local topography is a deciding factor in the direction of these latest movements. Therefore, it is an open question whether the glacial scratches in the vicinity of valleys, after all, give much information as to the movement of the general ice sheet. The discordance in the appended table of striæ between the lower and the higher ranges of altitude show the influence of topography.

It is apparent that the general movement of the ice in the Moravia quadrangle was from the northwest, such is the indication of striæ on higher altitudes. This prevailing direction of ice-motion does not necessarily imply that the general ice-sheet thus moved. As explained on earlier pages, the controlling lobe of this vicinity occupied the Cayuga valley which lies to the west. The lines of ice-movement, as has been established in several distant parts of the country, is always outward from the axis of such a lobe. If then the Cayuga valley lobe controlled the last movement of ice in the Moravia quadrangle there is accordance between the hypothesis and the direction of striæ.

In the whole area of this sheet but one locality was found indicating a direction of ice-movement from any other quadrant. Near the eastern margin of the sheet, a mile or so northeast of Rogers Corners, a dimly striated surface exists on the very top of a hill which the topographic map makes 1720 feet above sea level. These scratches are mere brushings, and the first time I noted them they were not read, feeling that they represented some accidental alignment of plough or road scraper markings. Later in this season, however, the same faint markings were again observed, and read. The next summer this area was visited, and the evidence of dim striations was read on still a different side of the highway. The average direction of these several readings is S. 45° W. The faintness of the brushings, and the weathered surfaces carrying them, both indicate greater age than do the striæ elsewhere on the sheet. The topography eastward suggests that this area may have been finally controlled by ice which moved towards the southwest, just as the ice of a lobe farther west has affected other parts of the sheet by the striæ trending to the southeast. On the basis then of control of ice-motion by the drainage lines eastward, we may account for these discordant striæ; and on the supposition that they present the work of the oncoming

Wisconsin ice-sheet we may understand their weathered and indefinite condition.

Few of the striated areas present much variety in direction. In only a couple of cases is there sufficient discordance to suppose that the scratches are not contemporaneous in origin. Southeast of Moravia between the 1400-foot and 1500-foot contours there appear to be two sets of striæ, one of which averages S. 72° E., and the other S. 41° E. On the rim of the Montville valley, where it drops into the Moravia valley, we also find discordant striæ, one set of which has the direction S. 51° E., and the other S. 26° E.; the first mentioned set evidently represents the more general movement of the over-riding ice, while the second is plainly the result of local topography.

About a mile southeast of Sempronius in a saddle between two prominent rock hills we find conclusive evidence of a minor tongue which fed across and through this sag. The vigorously striated surface here gives an average reading of S. 76° E., while the valley to the west obviously directed the ice in a general southeastern motion. A similar instance is also noted southeast of Nubia where the striæ average S. 73° E.

One mile west of Locke is an area which apparently gives us the motion of the general ice mass. The average course of the striæ here is S. 44° E. If these striæ were connected with the outmoving-ice from the Moravia lobe their normal direction would be a similar deflection to the west. There is no evidence at all showing that the Owasco valley ever induced a lobation of the ice-front sufficiently strong to offset the controlling influence of the Cayuga lobe.

Grouping the direction of striæ according to ranges in altitude it is seen that those found below the 1100-foot contour average S. 39.2° E.; those between 1100 and 1400 average S. 52.6° E.; between 1400 and 1700 the average direction is S. 69.3° E.; while the only striated surface above 1700 is the indefinite one already alluded to where the direction is S. 45° W.

The following table gives a condensed résumé of the principal striated areas arranged according to altitude; each direction represents the average of a great many individual readings:

800–1100	11–1200	12–1300	13–1500	15–1700	17–1800
S. 14° E.	S. 75° E.	S. 44° E.	S. 46° E.	S. 61° E.	S. 45° W
S. 26° E.	S. 57° E.	S. 50° E.	S. 48° E.	S. 71° E.	
S. 51° E.	S. 37° E.	S. 56° E.	S. 31° E.	S. 76° E.	
S. 66° E.		S. 51° E.	S. 49° E.		
		S. 45° E.	S. 55° E.		
			S. 72° E.		
			S. 73° E.		

Ice-Front Channels.

The several halts of a retreating ice-sheet naturally develop waterways not normal to ordinary conditions of rainfall. Often these waterways are narrow, occupying a slight depression sometimes incised in rock; more often, however, they are not cut entirely through the previously deposited drift. Again, they are broad channels indicating a wide shallow stream bearing drainage away from the melting ice; in this case an unusual quantity of bowlders, large and small, generally characterize the former water course. These bowlders may represent the unremoved heavier portions of the former drift deposits, as well as the débris melted from stranded ice-blocks being floated off by the waters flowing from the front of the glacier.

The two types of ice-front channels may be discriminated: (1) *Topographic*, or drainage ways usually following the sags between or leading into the valleys of the locality; (2) *Torrential*, or channels cut generally in previously deposited drift, and having locations possible only when an abnormal quantity of water is turned loose through an area that in post-glacial times has never carried any considerable drainage. The former type one might locate with some degree of accuracy on a topographic map, knowing only the general positions of bands of thickened drift. The torrential type, however, can scarcely be hypothecated on any normal premises. Ice-front channels of this type are found often in unexpected places, particularly where the ice has melted slowly and the drift in consequence has become very thick.

Topographic Type. (1) About a mile southwest of West Dryden is an area now covered by extensive swamps. This flat region leads away from northwestward falling contours to contours descend-

ing in the opposite direction on the Dryden sheet. The plentiful bowlders, as well as the suggestion of a channel toward the northern margin of the flat area, both indicate ice-front drainage. In some places it is evident that the drift has been quite completely swept away; this is particularly true in the crease which is indicative of a channel, cut by the narrower, more permanent form of the overflow stream.

(2) West Groton is situated on the northwest corner of a quadrangle formed by highways. Just south of the diagonally opposite corner from West Groton is a channel which lies slightly north of the axis of the valley leading southeastward to the village of Pleasant Valley. This channel dissects a loop of drift already described. It is a well marked crease, though it does not disclose the underlying rock.

(3) Beaver Brook, a tributary of Fall Creek, heads in a channel southeast of Lafayette. The channel here indicates a long period of overflowing glacial waters. The lateral tongue of ice from the lobe that persisted in Fall Creek valley stood for a considerable period in this valley, the drainage from which incised the overflow channel referred to.

(4) Another tributary valley of Fall Creek valley, leading southeast from the parallel of Rogers Corners, also was similarly occupied by a lateral tongue of ice, the drainage from which developed a channel leading into Dry Creek of the Cortland quadrangle. Fig. 12 gives an idea of the morainic accumulations built up during this halt of the ice.

(5) Again the tributary valley east of Como caused an analogous arrangement of drift and overflow channel. This channel likewise carried waters into a valley of the Cortland quadrangle.

(6) Leading eastward from the plexus of drift in which Fall Creek rises is a channel of glacial overflow incised in the rock, and leading into Skaneateles Inlet valley. This channel has already been alluded to under the discussion of drainage (p. 343). To some extent its development may be of post-glacial origin. The manner in which the drift north and west from the western terminus of the rock gorge portion of this channel has been eroded indicates that the post-glacial factor in its degradation is very unimportant.

(7) In connection with the formation of the drift loop just east of North Summer Hill the ice-front waters developed a channel

that has swept off much of the ground moraine leaving the surface of the country rock quite exposed. Reference was likewise made under the general consideration of drainage (p. 343) to this ice-front stream which gave the gorge to the southeast its present development. Here, too, the later post-glacial erosion has been slight.

(8) About one and a half miles due northwest of Summer Hill a typical ice-front channel now marks the divide area between Dry Run and the Summer Hill tributary of Fall Creek. This channel is practically of immediate ice-front drainage development. For a time, however, probably rather brief, the channel was the overflow of a slight lake held in the upper portion of Dry Run valley.

(9) Hollow Brook, west of Locke, occupies now for a short distance, near the boundary of Genoa and Venice townships, the course of an ice-front channel, which is crossed by the east-west highway at the point where the present stream occupies the former waterway. The genesis of this overflow channel is connected with topographic relationships found on the Genoa sheet.

Torrential Type. As stated above, this type of channel is confined to areas of thickened drift, that is, areas where the ice-front retreated very gradually. While no pretense is made at mapping all channels of this type, it has been thought well nevertheless to make specific reference to a few of the better developed illustrations, or to vicinities where the type abounds.

(1) On the eastern wall of the Freeville-Moravia valley, it has already been noted that the drift assumes a very morainic aspect. The torrential overflow channel is here common, and is easily differentiated from post-glacial erosion lines. The drainage established since the complete retreat of the ice has suffered but slight changes. Consequently, the deserted channels, since it is evident that they bear no relationship to post-glacial waterways, are plainly of the ice-front type.

(2) In the kame moraine areas from Freeville to McLean and northward one notes illustrations of the torrential type of ice-front channels. This would be expected, for here the massive accumulations of drift, prevailingly washed in character, bespeak an unusual quantity of ice-front drainage. Some of these channels indicate a sub-glacial origin, as it is impossible to associate them with the normal development of channels cut by water flow along

the lines induced by gravity. While only one esker (fig. 18) has been mapped in this region, it is nevertheless possible that some of the short and isolated ridges of washed drift do represent segments of subglacially aggraded drainage lines. It is this association that prompts the above suggestion concerning the genesis of some of the erosion channels noted in the area.

(3) Just a few rods east of the third road to the left going south from Como is a deserted water course which has no connection with recent drainage; its proportions are entirely out of harmony with the work that might be done by the waters assembling from the catchment basin to which the channel is contiguous; it is direct in course, leading southward, and plainly has the marks of vigorous initial development.

(4) East of Sempronius the thickened drift indicates a long halt of the ice. Extending southward from this area, in which Fall Creek now heads, are several clean cut channels indicating the work done by ice-front drainage.

(5) In the region of thickened drift north of North Lansing I have also observed waterways that obviously are not due to post-glacial erosion.

Ice-Walled Channels.

Gilbert[37] and Fairchild[38] have described the peculiar terraces and benches produced by water courses, one wall of which was the ice in position. The recent work of Fairchild in the Mohawk valley[39] calls attention to a variety of such water courses.

A few instances of these ice-walled channels are noted on the Moravia quadrangle. The development attained is not marked since in the higher altitudes of this sheet no water bodies persisted any great length of time. Where a rock slope abutted the ice, and the ice fed around this slope in either direction, the topography otherwise forming the conditions for ponded waters on either side, then as the ice retreated the water on one side or the other would coalesce or flow down into the other body. The channel through which the water spilled consisted of rock on one side and ice on the other. If the ice were permanent for some time, normal

[37] *Bull. Geol. Soc. Am.*, vol. 8 (1897), p. 285.

[38] *N. Y. State Mus., 22nd. Rep.* of State Geologist (1902), pp. 123–130.

[39] *Ibid., 21st Rep.* of State Geologist (1901), pp. 135–147.

methods of erosion would incise the rock slope, and a resulting bench and terrace would now indicate the course of this former overflow stream.

Where the highway leading southeastward from Moravia to North Summer Hill skirts the southern slope of the rock salient facing Montville we note at about the 1200-foot contour, the first evidence of one of these former stream courses. The appearance from the highway, however, is not suggestive of such a channel, but a short walk northward around the face of the salient leads one to a more conspicuous development of the former stream course. This point of overflow obviously taken by the water held in the valley eastward towards Morse Mill succeeded a higher channel which led the ponded waters about the brow of the hill and formed a conspicuous cliff and terrace extending about the prow and the southeastern part of the slope fairly parallel with the 1340-foot contour. Southward from this highway the course of the channel last traced drops, and at about one-quarter of a mile from the road it may be traced for some distance where it has smoothed out the morainic topography that characterizes the northern slope of Dry Run valley. Likewise, about one hundred feet lower in altitude may be traced the continuation of the first mentioned channel.

On the southern wall of Dry Run valley there is noted a marked over-steepening, not due to any lithological irregularity in the salient, which here is included within the district encompassed by a highway extending to the east and another extending southward and then eastward. The case of a deserted stream course here, while apparent, is not so clear as in the two just described.

The western slope of the hill south of Asbury is conspicuously free of drift, a condition due to the sweep of waters from the north between the ice and this hill. No pronounced bench was developed, but the rock over quite a width and vertical range has been fairly well cleared of glacial rubbish.

The slopes of many salients found on the east wall of Fall Creek valley also bear benches probably due to a similar cause. It is seen from the topographic map that this area is cut up by frequent and wide valleys, thus producing a medley of salients between which impounded waters escape successively to the lower levels, and in doing so, being held against the slope by ice, have channeled the rocks in varying degrees. I have not mapped these since in

no case do any of them present a linear extension of more than a few rods.

Drift of an Earlier Ice Invasion.

Positive evidence that the region included in the Moravia quadrangle was glaciated previously to the Wisconsin invasion was not found in this investigation. No contact between drift of different ages has been noted, neither have I observed individual deposits which suggest drift older than the Wisconsin. The strongest suggestion of any earlier glaciation is the presence of apparent interglacial drainage lines.

In spite of the lack of direct or positive evidence of the existence of an older drift sheet, in all probability this region was glaciated once at least previous to the Wisconsin invasion. Several lines of indirect proof point to this conclusion.

The work of Leverett,[40] Salisbury,[41] Woodworth,[42] Fuller,[43] Clapp,[44] and others[45] along parallels both east and west of the Finger lake district gives cumulative evidence of the existence of drift older than the Wisconsin. Knowing that ice of an Illinoian or some older sheet reached into southern New England and across Long Island into New Jersey, and that drift classified as Kansas has been found in northwestern Pennsylvania, the chance that the plateau section of New York state escaped glaciation contemporaneous with the ice depositing such drift in those areas is indeed slight. Indirectly, then, we infer that the presence of older ice on both sides of the Finger lake region and farther south implies that this region itself was covered by that ice.

The amount of erosion accomplished in these Finger lake valleys suggests, according to Tarr,[46] more than one ice-invasion. In acounting for some of the hanging valleys he alludes to the

[40] *Monograph*, xli, U. S. Geol. Survey (1902), p. 228.

[41] Geological Survey of New Jersey, *Annual Report for 1893*, pp. 73, etc.; vol. v (1902), pp. 187–89, 751–82.

[42] *N. Y. State Museum, Bulletin 48* (1901), pp. 618–70.

[43] *American Geologist*, vol. xxxii (1903), pp. 308–12.

[44] *Bull. Geol. Soc. Am.*, vol. xviii (1908), pp. 505–556.

[45] A. C. Veatch: *Jour. of Geol.*, vol. xi (1903), pp. 762–76. L. H. Woolsey: *Beaver Folio*, no. 134 (Penn.), U. S. Geol. Surv. (1905), p. 7.

[46] *Am. Geol.*, vol. xxiii (1904), p. 284. *Bull. Geol. Soc. Am.*, vol. 16 (1905), pp. 239–40. *Jour. of Geol.*, vol. xiv (1906), pp. 20–21. *Pop. Sci. Monthly* (May, 1906), pp. 392–93.

probability of multiple glaciation. "Through valleys"[47] offer equally pertinent hints of repeated ice-invasions.

Possible evidence of an earlier invasion is indicated also by the scattered hints of ice-dammed lakes older than the lakes held up in front of the retreating Wisconsin sheet. No data is available for a more accurate time-definition; the lakes may have skirted the front of the advancing Wisconsin ice; they may mark the advance or retreat of an earlier invasion. The shore lines of these older lakes so far as traced show discrepancy in attitude when compared with the shore lines of the more recent ice-front lakes. It is obvious, furthermore, that every ice-invasion of this Finger lake region witnessed the growth and decadence of such lakes. The strength of shore phenomena developed by the static water bodies characterizing the progress or retreat of any ice-sheet has a direct connection with the duration of the halt which occasioned the static body of water. If, therefore, the ice-dammed lakes in this region held up, for example, by the Illinoian ice-invasion had a duration comparable with the Wisconsin Lake Warren, it is probable that shore lines would have been developed that might locally withstand even one or more later ice-invasions and be observed today. Such phenomena have been tentatively studied in the valley of Lake Keuka;[48] if found in other of the Finger lake valleys, correlating data may aid in arriving more closely at the time of their origin.

On the supposition that this area has been glaciated previous to the Wisconsin invasion, we may consider the effects produced on an older drift sheet by another incursion of ice. These effects would be controlled somewhat by the topography, and to a much less degree by the length of the interglacial period. The drift which accumulated in transverse valleys obviously would suffer less through a second invasion of ice than would the glacial deposits made in longitudinal valleys. For this reason, then, older drift sheets should be better preserved in valleys transverse to the line of movement of the later ice-invasion. The bearing that the length of the interglacial period has on the question arises through the amount of soil that would be developed in the lapse of glaciation, and also in time through which the till already

[47] The designation used by Tarr, *Bull. Geol. Soc. Am.*, vol. 16 (1905), p. 233.
[48] F. Carney: *The Am. Jour. of Sc.*, vol. xxiii (1907), pp. 325–335.

deposited would have for induration. A drift sheet when undisturbed through two time units would assume a stage of induration that would not be reached by a drift sheet in one time unit. While the condition of induration attained by the till would but slightly control its resistance to the abrasive powers of another sheet, it is apparent nevertheless that the factor has some weight.

All evidence points to the conclusion that throughout this part of the Allegheny plateau the Wisconsin ice-sheet was vigorous. The erosion which it is assumed has been accomplished in rock valleys would very evidently accomplish work of the same degree on a till sheet previously deposited in those valleys. It follows, then, that a pre-Wisconsin drift sheet in this region must have suffered much from the influence of a later invasion. The older drift in the longitudinal valleys especially must have been largely removed, and in semi-protected areas suffered much disturbance.

The vigorousness of the Wisconsin ice is evidenced by the great mass of its morainal deposits. Thus while this last ice invasion did much destructive work on a till sheet already in this area, at the same time it produced rubbish which now doubtless buries much of this older drift.

A second invasion would also evidently affect previously deposited drift which escaped removal in bringing about in such old drift a condition of more or less complete induration. This is accomplished entirely through the weight of the over-riding ice. While I have not seen in the Moravia quadrangle any sections of drift which suggest an indurated condition, nevertheless the reports of well drillers in the region are very suggestive of the existence of such hard till in many widely separated parts of the quadrangle. It is entirely possible that this hard bluish till was deposited by the advancing Wisconsin ice; the final interpretation must involve its study over a wider area. My purpose is to record the fact of its general distribution in the Moravia sheet.

All the evidence here offered as bearing on the question of a possible pre-Wisconsin drift sheet is found in well records. I will accordingly refer to some particular localities where the drill has revealed the presence of hard blue clay. I appreciate the misconceptions that drillers often have of the material through which their drills pass, yet we must grant that in the presence of cumulative evidence of such indurated bluish drift there must be something in common with these wide-scattered deposits:

(1) About two miles south of Moravia Mr. J. C. Rounds sunk a well which shows 75 feet of blue clay. This well lies north of the first valley loop proceeding southward from Moravia. It is in the valley bottom, and the water flows with some activity from the pipe. While details as to the depth and other material passed through in this well are lacking, the certainty expressed as to the thickness of the blue clay is given as the writer had it.

(2) Directly north of the Lansing overflow channel, wells found along the east-west line approximately on the 1200-foot contour report several feet of blue clay.

(3) At Locke there are several wells, some of which flow, and all of which give a record of blue clay. That of Burdette Robinson, who lives a quarter of a mile southwest of the village, shows 160 feet of blue clay overlain by six feet of gravel. That of C. E. Parks just across the highway shows 170 feet of blue clay overlain by 10 feet of gravel. North of the village a short distance A. A. Slocum has a well which gives 80 feet of blue clay beneath some four feet of light-colored clay. All of these wells reported gravel beneath the blue clay. In the part of the Moravia-Locke valley where these wells are located there is evidence of slight glacial erosion by Wisconsin ice. At this point the valley divides; the western arm bottoms in rock not far from the wells; in the eastern branch a well one mile distant gives rock at 96 feet. Overdeepening which characterizes the main valley a few miles north is absent here. We would expect it to be absent near the point where the longitudinal valley divides because the salient of rock between the two lesser valleys protects that portion of the major valley near its base from ice-erosion. Hence the presence here of drift older than the deposits made by the retreating Wisconsin ice is not improbable.

(4) On the uplands north and east of Groton the wells with very few exceptions show several feet of blue clay.

(5) About a half mile east of Jones Corners a well shows 60 feet of blue clay beneath twelve feet of gravel. This is on the farm of George Barrows. At the Summer Hill creamery a driven well shows 28 feet of blue clay beneath twelve feet of gravel.

(6) Several wells about a mile and a half southeast of Peruville give a record of blue clay.

(7) On the property of John M. Sherwood, one mile west of McLean, is a well which revealed forty feet of blue clay beneath

sixteen feet of gravel. Gravel also underlies the clay. The well of D. W. Rowley across the highway has a similar record.

Obviously there are apt to be several lines of discrepancy in these well records because in all cases they were given the writer from memory. I place slight value on the number of feet of clay or other material alleged in the wells. The constant report, however, of an exceedingly hard horizon is suggestive of an indurated drift which may imply much antiquity.

ACKNOWLEDGMENTS

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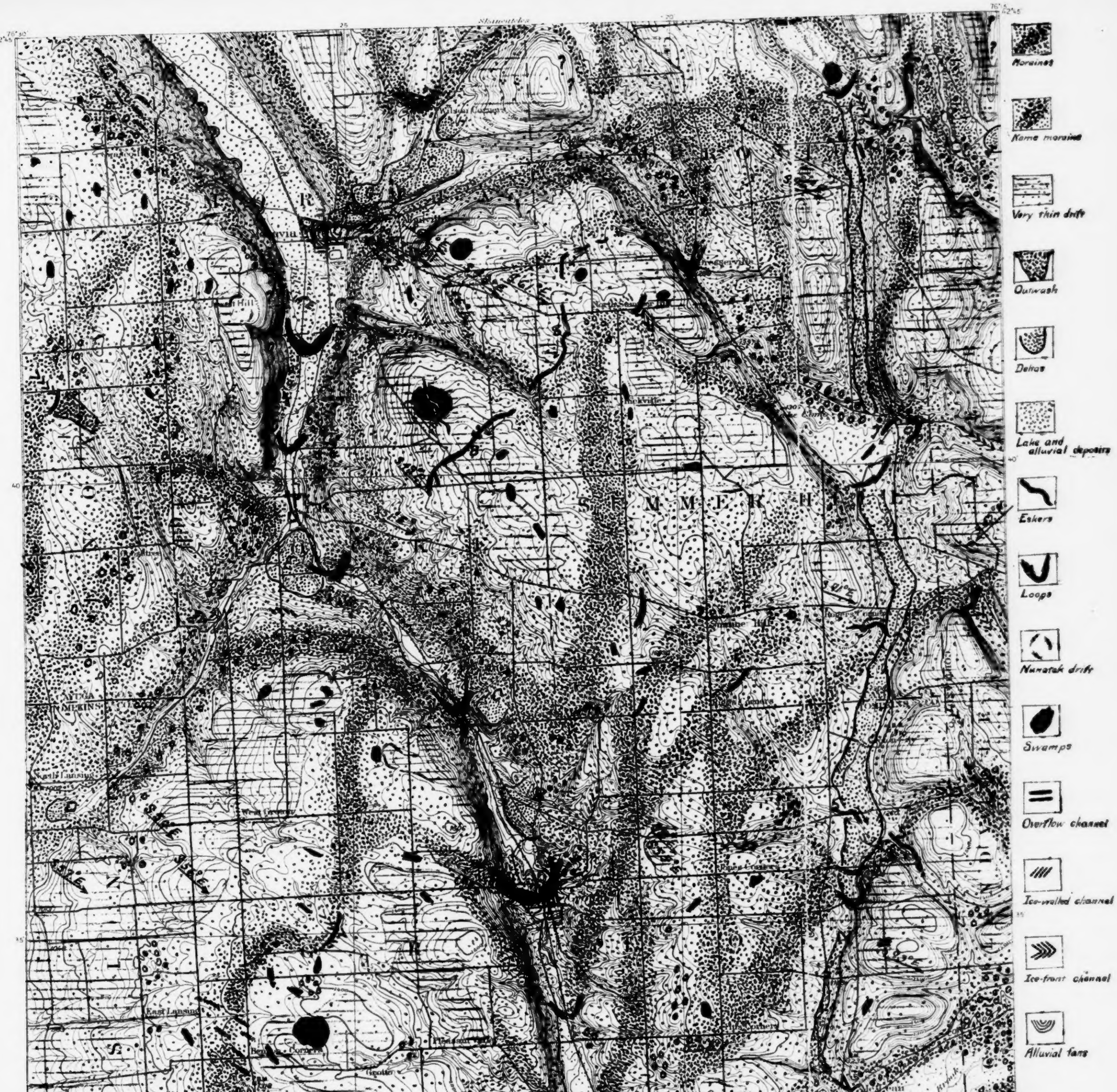
Plate XII. A Pleistocene Map of the Moravia Sheet.

The overlay gives hypothetical retreatal positions of the ice-front as suggested by the moraines and their valley loops.

The direction of striæ represent in each case the average of many readings.

The eskers are numbered, 1 to 9; and the deltas are marked by the letters, A to J.

In all other particulars the legend is indicated on the margin of the plate.



Skaneateles
(Dryden)
Moraines
Kame moraines
Very thin drift
Outwash
Deltas
Lake and alluvial deposits
Eskers
Loops
Nunatak drift
Swamps
Overflow channel
Ice-walled channel
Ice-front channel
Alluvial fans

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[Bibliographical names are in caps]